3
9
17
Copy

SCIENCE

OCTOBER 5, 1951

VOLUME 114 NUMBER 2962

Annual Equipment Issue

Chemical Analysis by Neutron Spectroscopy: *T. I. Taylor, Robert H. Anderson,* and *W. W. Havens, Jr.* 341

A Microfluorometric Scanner for the Differential Detection of Cells: Application to Exfoliative Cytology: *Robert C. Mellors* and *Reuben Silver* 356

Technical Papers

Series-Aiding Phototube Bridge: *L. G. Glasser* 360

A Simple Instrument for the Determination of ACH: *J. B. Davidson* 361

Barostat for High-Altitude Chamber: *H. F. Brubach* and *H. Specht* 362

Determination of Radioactivity by Solution in a Liquid Scintillator: *M. S. Raben* and *N. Bloembergen* 363

A Recording Warburg Apparatus: *William Arnold, E. W. Burdette,* and *J. B. Davidson* 364

Comments and Communications

The Exponential Decay Law in Spray De-electrification: *Chester T. O'Konski* 368

A Simple Sampling Device for Submerged Cultures: *H. A. Walch, Jr., G. J. Jann,* and *A. J. Salle* 368

Book Reviews

Industrial Medicine on the Plutonium Project; Reports on Progress in Physics; Eyes and Industry; Eyes in Industry 369

Association Affairs

The Annual Exposition of Science and Industry: *Raymond L. Taylor* 372

News and Notes 374

New Tools for Research 3

Meetings & Conferences 42

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

RANGE — is continuously adjustable from a minimum of —0.1 to +1 mv . . . up to a maximum of —2 to +20 mv.

ZERO SUPPRESSION — uncalibrated coarse and fine . . . is continuously adjustable from —50 to +50 mv.

range and zero suppression are continuously adjustable

Just turn a knob . . . twist a dial . . . and you have adjusted this new Speedomax Recorder to the exact specs required for the automatic data-charting job at hand.

Turning the ZERO knob varies zero suppression . . . pushes off-scale that portion of the range in which you are not interested . . . spreads the few millivolts you want to watch across full width of the 9⅞" Speedomax chart. Twisting the RANGE dial calibrates the recorder so that its scale represents the range span in which changes occur.

With full scale pen speed of 3, 2, even 1 second . . . limit of error only 0.3% of range, Speedomax proves especially useful for measuring:

Force, weight, etc.—with load cells. Adjustable zero compensates for tare. Range is adjusted to provide desired calibration.

Temperature or temperature-difference—with thermocouples. Minute changes can be measured with extreme sensitivity.

Speed—with electric tachometers. Change of speed can be measured over a narrow band in detailed studies of motors, engine governors, etc.

Voltage—from other transducers and amplifiers.

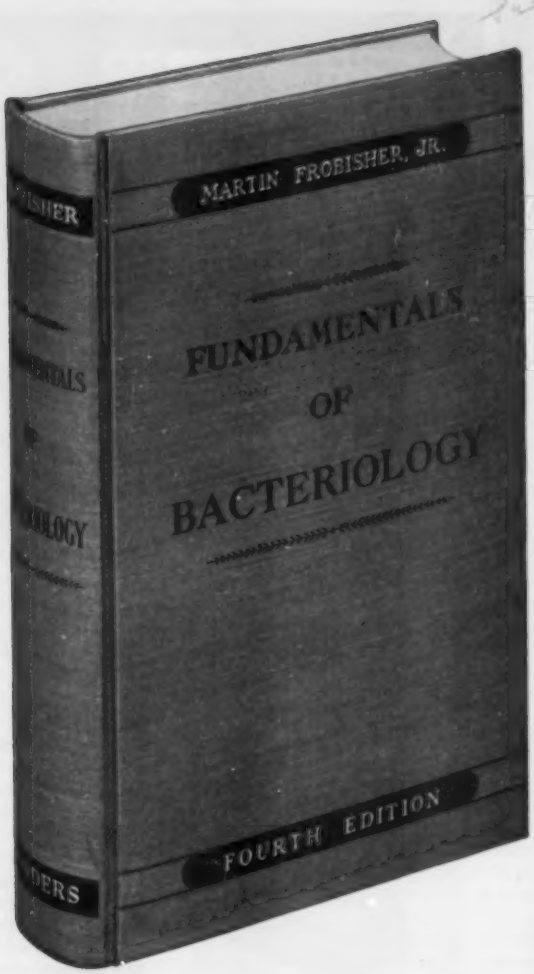
For further information write–

LEEDS NORTHRUP

4926 Stenton Ave.
Philadelphia 44, Pa.

Jrl Ad EM9(3)

Q1
.S35
2nd Set



✓ **Completeness**

✓ **Authority**

✓ **Hundreds of helpful illustrations**

✓ **Logical organization**

✓ **and most important of all . . .**

. . . that great, intangible, wonderful quality that makes teaching a joy, learning less tedious, and a textbook a gem.

Student interest is what we're talking about.

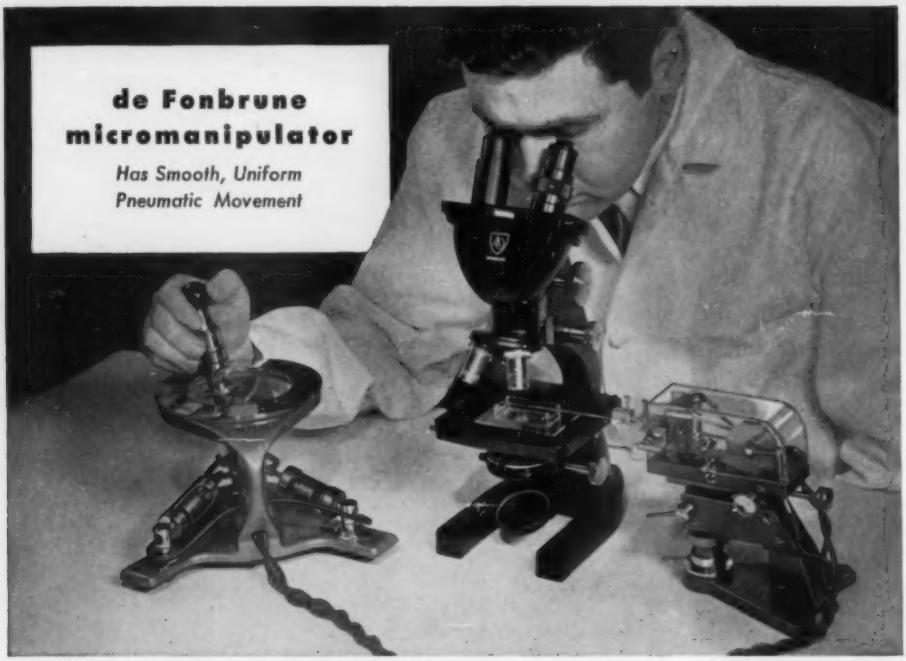
Frobisher has it.

That's why **Frobisher** is one of the most widely used bacteriology texts in America today. Have you looked at a copy lately?

By Martin FROBISHER, Jr., Sc.D., U. S. Public Health Service and Emory University.
936 pages with 420 illustrations. $5.50. Fourth Edition.

W. B. SAUNDERS COMPANY

West Washington Square **Philadelphia 5**



Affords new simplicity and flexibility for micro-studies in biological or chemical technics

Improved de Fonbrune Micro-Forge With Binocular Body

Specifically developed for use in the fabrication of simple and intricate micro-tools of glass or metal under controlled conditions. Use of the de Fonbrune micro-forge is recommended with any type micromanipulator. The forge is now built with binocular stereoscopic microscope. With this modification, the image is observed erect—not inverted—in three dimensions, an important factor in rapid, accurate work.

The de Fonbrune micromanipulator, incorporating a pneumatic pump system, has proved exceptionally satisfactory for micro-studies in many fields. In the biological sciences the de Fonbrune instrument is used in cell dissection and isolation . . . micro-injection and operation on the protozoa . . . pH studies on living cells . . . isolation and transfer of single bacteria, etc. This flexible instrument has proved equally serviceable in study of fibers and yeast cells, in investigating oils, rust deposits, colloidal, and other materials.

Manufactured under exclusive license of the French patents, the de Fonbrune micromanipulator consists of a manipulator and receiver. These units may be used with any type of microscope . . . arranged for right or left hand operation. In use, the micro-tool is mounted on the receiver. Impulses from the pneumatic pumps of the manipulator are transmitted to the tool through sensitive metallic membranes. Within a range of 3 mm, the micro-instrument may be moved in any plane or angle by a single control. Ratio of displacement of control lever and micro-tool may be adjusted from 1:50 to 1:2,500 depending on range desired.

Write for prices and descriptive bulletin T114.

aloe scientific
DIVISION OF A. S. ALOE COMPANY
5655 Kingsbury • St. Louis 12, Missouri

aloe

SCIENCE

Gladys M. Keener
Executive Editor

AAAS EDITORIAL BOARD
(*Terms Expire June 30, 1952*)

Howard A. Meyerhoff, Chairman
William R. Amberson Karl Lark-Horovitz
Bentley Glass Lorin J. Mullins

F. A. Moulton, Advertising Representative

New Tools for Research

THE common concern that links all the experimental sciences is their dependence on the measuring process. Although the instruments for making measurements—the tools of research—are based on the discoveries of physics and the designs of engineering, they are adapted, refined, and applied by all the sciences. Instrumentation is the common denominator of the sciences—the common thread of physics that ties them together.

Perhaps the most striking aspect of the newer developments in instrumentation is their universal usefulness. The same basic measurement, and therefore the same instrument, is frequently of interest in a number of sciences. Consider, for instance, the sciences that are applying the unique analytical capabilities of the mass spectrometer which, in some new designs, can now analyze solids and liquids, as well as gases. Many problems common in all fields have more direct bearing on the choice of instrumentation than either the application of the measurement or the thing being measured. The most fundamental influence of all is the existence in the general measurement process of many elements or steps that are common not only to all sciences but to all instruments and are quite independent of the particular quality, quantity, condition, and factors to be measured. The primary detector, transducer, or pickup often gives an output signal of an electrical nature that may be translated into variations in pneumatic pressure, sound or light intensity, mechanical displacement, changes in color, or other output. The signal once obtained may undergo the further steps of transmission, amplification, indication, recording, controlling, reduction, and analysis. Somewhere along the way it may be converted from analog to digital representation by quantization. Once the *transducer* takes the signal, the later steps in the measurement process have lost any real dependence on the original quantity or thing being measured.

Many significant advances have recently been made. The excitation possibilities of α-, β-, γ-, and x-rays have been recently augmented by quantitative use of neutron beams, modulated by composition or structure of materials. The transmission of large quantities of data at high speed has developed a specialized field of information handling, and radio telemetry is being rapidly perfected for military purposes. The same techniques make possible the rapid transmission of all sorts of measurements in biological and physiological experiments on human or animal subjects while they go freely about their accustomed routine.

The amplification of signals for measurement purposes has always used the same type of amplification that is used in radio. Within the past few years the development of the transistor and new principles applied on the traveling-wave tube give promise of radical improvements in amplifying devices. The development of the saturable reactor or magnetic amplifier points to other possibilities for increasing by several orders of magnitude the faintest signals.

Within the past year a number of generally applicable analog-to-digital converters have been announced, some of them capable of sampling 50,000 times per second, with an accuracy of 1 part in 64. Another type records with accuracy of 1 part per thousand at a sampling rate of about 500 per second. Steady progress has been made in recording data. Writing speeds on cathode-ray oscilloscopes approach the speed of light, and successive photographs have been taken at rates of a million times per second. Facsimile recording and xerography both promise to handle large amounts of information rapidly and cheaply. Provision for automatic control may be built into any instrument where a signal is present that can be measured and compared with a desired value.

The use of high-speed computers—both digital and analog—in the automatic evaluation and analysis of data while it is being taken offers significant possibilities in automatic guidance and control. These advances in the science of measurement, rapidly assimilated by all other sciences, will accelerate their progress.

WILLIAM A. WILDHACK
National Bureau of Standards

SCIENCE, founded in 1880, is published each Friday by the American Association for the Advancement of Science at the Business Press, 10 McGovern Ave., Lancaster, Pa. Entered as second-class matter at the Post Office at Lancaster, Pa., January 13, 1948, under the Act of March 3, 1879. Acceptance for mailing at the special rate postage provided for in the Act of February 28, 1925, embodied in Paragraph (d-2) Section 34.40 P. L. & R. of 1948.

All correspondence should be sent to SCIENCE, 1515 Massachusetts Ave., N.W., Washington 5, D. C. The AAAS assumes no responsibility for the safety of manuscripts or for the opinions expressed by contributors. Four weeks' notice is required for change of address, and an address stencil label from a recent issue must be furnished. Claims for a missing number will be allowed only if received within 60 days from date of issue.

Annual subscriptions, $7.50; single copies, $.25; foreign postage, outside the Pan-American Union, $1.00; Canadian postage, $.50. Special rates to members of the AAAS.

The AAAS also publishes THE SCIENTIFIC MONTHLY. Subscription and advertising rates on request.

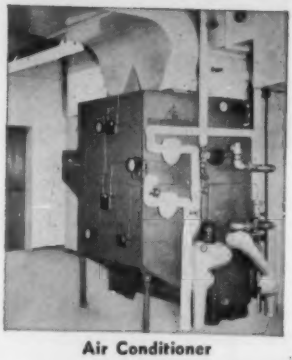
NIAGARA AIR ENGINEERING EQUIPMENT

NIAGARA HIGH PRECISION AIR CONDITIONERS

Complete function air conditioning for the most exacting duty, producing any condition in the range 40°F to 140°F. Provides air at saturation. Provides, also, sub-freezing dew point temperatures when Niagara "No Frost" Liquid is used in the spray chamber.

Accurate Humidity Control Using Hygrol Absorbent Liquid

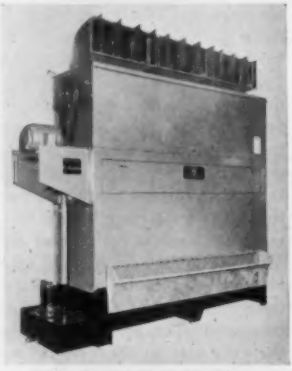
Low dew points under accurate and automatic control are produced by spraying Hygrol Liquid absorbent in the air stream. Hygrol is a liquid, not a salt solution; its use avoids corrosion and maintenance troubles. Automatic reconcentration provides continuous operation.



Air Conditioner

NIAGARA "NO FROST" METHOD

For refrigeration with control of temperatures and humidity with complete freedom from frost and defrosting interruption and sustained full capacity in temperature ranges 32°F to minus 100°F. Uses Niagara "No Frost" Liquid automatically reconcentrated.



"No-Frost" Spray Cooler

NIAGARA AERO HEAT EXCHANGERS

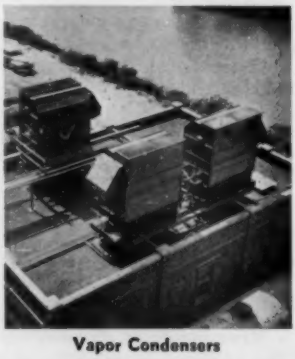
For the cooling and accurate control of temperatures of liquids and gases, without refrigeration and independent of a supply of cooling water, in the range 160°F down to 85°F at 75°F. Wet Bulb Atmospheric Temperature.

Vapor Condenser

Independent of a supply of condensing water. Takes advantage of changes in atmospheric wet bulb temperature to maintain a high vacuum. Successfully applied to distillate and reflux cooling, also, refrigerant condensers.

Aero After Cooler

Independent of cooling water supply. Produces compressed air or gas with lower moisture content than is possible with average surface water cooling.



Vapor Condensers

Write for bulletins describing the uses of these and other Niagara units and for physical and engineering data. Your inquiry is asked on matters involving equipment in the fields of heat transfer and air engineering and for laboratory air conditioning.

NIAGARA BLOWER COMPANY, Dept. SW, 405 Lexington Ave., New York 17, N. Y.

Field Engineers in Principal Cities

Announcing

CATALOG LP-31!

CORNING'S NEW LISTING OF LABORATORY GLASSWARE... THE LABORATORY TECHNICIAN'S HANDBOOK.

- Completely revised from cover to cover with many new items listed
- Thumb indexed for easy reference
- PYREX, VYCOR, and CORNING brand Laboratory Glassware described and illustrated in detail
- Valuable pointers on how to use the equipment more effectively.

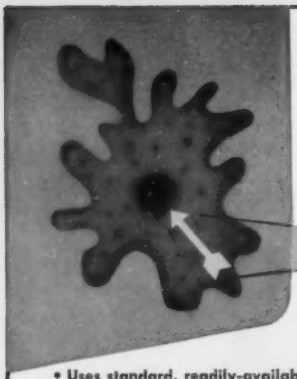
Your inquiries for special apparatus or modifications of standard listed items are invited.

If you have not already received your catalog, a request on your company letterhead will bring you a copy.

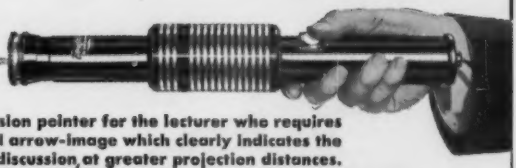
CORNING GLASS WORKS PYREX **CORNING, N. Y.**

Corning means research in Glass

1851 · 100 YEARS OF MAKING GLASS BETTER AND MORE USEFUL · 1951



Give point to your lectures with the Edualite PROJECTION POINTER



The perfect precision pointer for the lecturer who requires a sharply defined arrow-image which clearly indicates the specific point of discussion, at greater projection distances.

- Uses standard, readily-available, easily replaceable 32 candle-power, low-voltage automotive lamp.
- Operates on ordinary house current, 115 Volt AC, with transformer built into DELUXE, permanent carrying case. Complete unit Underwriters' approved.
- Made from precision, lathe-machined, light-weight metals, completely anodized. Perfectly hand-balanced with feather-touch momentary switch.
- Aspheric, highest-efficiency optical system, projecting a crisp, sharp, intensely brilliant arrow on the screen for extra-long projection throw.
- Helical, micro-focusing ground and polished objective.
- Supplied with full 25 feet of detachable line cord—all contained in solid wood-framed leatherette-lined fitted instrument case.

$49.50 LIST PRICE complete with line cord, transformer, and carrying case.

Manufactured by Edualite OPTICAL CO., INC.
200 North Water St., Peekskill, N. Y.

THE CSI HIGH SPEED ANGLE CENTRIFUGE

CS-26

- 20,000 RCF x g
- Two styles interchangeable rotors for maximum flexibility.
- Self-balancing precision rotors machined from special hand-forged duralumin alloy.
- Modern design unit housing with integral control panel and guard. Fully corrosion resistant.
- Tube angle 32°.
- Speed control fully adjustable.
- Low in first cost.
- Low in maintenance cost.

FOR INFORMATION WRITE DEPT. "S"

CSI **CUSTOM SCIENTIFIC INSTRUMENTS, INC.** CSI
Post Office Box 170 Arlington, N. J.
MANUFACTURERS OF CUSTOM-BUILT LABORATORY EQUIPMENT

WAR SURPLUS OPTICAL BARGAINS

35 POWER *ERECTING* MICROSCOPE

DESIGNED FOR GREATER UTILITY . . . VERSATILITY

AMAZING CLARITY • Gives you 3" of Working Space from Objective to Platform.

Swings To Any Position . . . Easily, Quickly!

A remarkable Instrument! Exceptional Value! Prism Erectors give you an erect image—exactly as your eye sees it, not upside-down as in an ordinary Microscope. Ramsden Eye-Piece permits fine precision focusing. 3-Element color corrected objective — 1" diameter. Microscope body is of brass with black crackle finish. Working distance from objective to object is almost 3", which permits any work, dissection, tooling, etc. to be carried on "under power" while looking through Microscope. The Instrument is 6½" long with base 7" × 9". Only because we were able to utilize some war surplus parts are we able to offer such a fine Optical Instrument—easily worth $75.00—at this special low price.

Stock No. 970-W .... $29.50 Postpaid

DON'T MISS THIS BARGAIN • SATISFACTION GUARANTEED

LOOK AT THESE BARGAINS!

MOUNTED PROJECTION LENS—Speed F/1.9 . . . F.L. 15 mm. $22.00 value for $7.50. Low Reflection Coated. Used on 8 or 16 mm. Movie Projectors . . . or to make a Desk Viewer or Editor . . . for 16 mm. Micro-film Reader . . . for Contour Projector for very small items.
Stock #4045-W ..... $7.50 Postpaid

LENS CLEANING TISSUE—1st quality, sheet size 11" x 7½". Made to Gov't. spec. Free of abrasives. High wet strength.
Stock #721-W ..... 500 sheets ... ... $1.00 Postpaid

SLIDE PROJECTOR SETS—Consist of all unmounted lenses you need to make the following size projectors:
Stock #4029-W—35 mm. ..... $2.85 Postpaid
Stock #4038-W ..... 2¼" x 2¼" ..... $3.35 Postpaid
Stock #4039-W ..... 2½" x 3½" ..... $3.35 Postpaid

LOOK! LOOK! LOOK!

Sheet Polarizing Material—
Stock #691-W ..... Pair of 1" dia. Circles ... ... 29¢ Pstpd.
Stock #692-W ..... Pair of 2" dia. Circles ..... 35¢ Pstpd.

SO MUCH *for* SO LITTLE!

SIMPLE LENS KITS!—Kits include plainly written, illustrated booklet showing how you can build lots of optical items. Use these lenses in experimental optics, building **TELESCOPES**, low power Microscopes, etc.
Stock #2-W—10 lenses ..... $1.00 Postpaid
Stock #3-W—45 lenses ..... $5.00 Postpaid
Stock #10-W—80 lenses ..... $10.00 Postpaid

MOUNTED ANASTIGMAT LENS—Free booklet with your order: "How to Make Your Own Enlarger."
Speed f/7.7, focal length approx. 127 mms. Suitable for pictures, negatives, positives up to 3½ × 4¼".
Stock No. 8004-W ..... $7.50 Postpaid

TERRIFIC BARGAIN! BUBBLE SEXTANT

BRAND NEW and with Automatic Electric Averaging Device and Illuminated Averaging Disc for nighttime use. Govt. cost $217. Though brand new, we have re-checked Bubble and Collimation and guarantee perfect working order. Price includes wooden Carrying Case. Full directions for use accompany each shipment.
Stock #935-W ..... $32.50 Postpaid

NON - ABSORBING BEAM - SPLITTING MIRROR—Latest development! Optically flat to ¼ wave length. Size: 1-15/16" x 2-15/16"—⅛" thick. Reflects approximately 50% and transmits approximately 50%. No light is absorbed. Has a three-layered film which accomplishes non-aborption.
Stock #567-W ..... $5.00 Postpaid

RONCHI RULINGS

BLACK LINE GRATING

Plate glass with etched parallel black lines—space between the lines is same as thickness of the ruled line itself. Normally cost $4.00 to $5.00 per sq. inch.

1 in. x 1 in. Stock No.	Lines Per In.	Price	2 in. x 2 in. Stock No.	Lines Per In.	Price
2122-W	65	$ .75	2133-W	65	$1.50
2126-W	85	.75	2134-W	85	1.50
2127-W	110	1.00	2136-W	110	2.00
2128-W	120	1.00	2137-W	120	2.00
2129-W	133	1.00	2138-W	133	2.00
2130-W	150	1.00	2139-W	150	2.00
2131-W	175	1.00	2140-W	175	2.00

All above sent Postpaid.

UTILITY MAGNIFIERS

Greater Power! Wider, Flatter Field!

- Ring provided to "lock" in focus.
- Excellent clarity and sharpness right out to edge of field.
- Double lens systems. Eye Lens has clear diam. of 1 7/16", Objective Lens 1 3/8".

5 Power Magnifier
Stock No. 732-W ..... $12.95 Postpaid
6½ Power Magnifier
Stock No. 733-W ..... $15.95 Postpaid

8 Power ELBOW Telescope
OUR PRICE $27.50

Big 2" diameter objective. All lenses Achromatic. Amici prism erects the image. 4 built-in filters—clear, amber, neutral and red. Slightly used condition but all guaranteed for perfect working order. Weight 5 lbs.
Stock #943-W $27.50 Pstpd.

BUBBLE SEXTANT—TYPE A-8A. Excellent condition but may be slightly used. Each has been carefully checked and collimated. Averaging device for nighttime use. Carrying Case and instruction booklet included. Gov't cost about $325.00 **Stock #946-W ..... $32.50 Postpaid**

TELESCOPE EYE-PIECE—Consists of 2 Achromatic lenses F.L. 28 mm. in a metal mount.
Stock #3140-W ..... $4.50 Postpaid

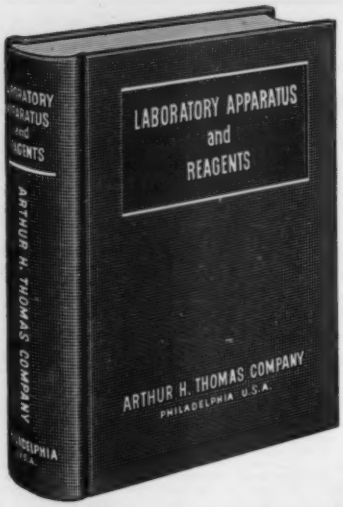
IF YOU'RE INTERESTED IN OPTICAL BARGAINS
Write for FREE CATALOG W We Have Literally Millions of War Surplus Lenses and Prisms for Sale at Bargain Prices. Numerous Types of Instruments Too!

ORDER BY STOCK NO. Send Check or M.O. Satisfaction Guaranteed

EDMUND SCIENTIFIC CORP. Formerly EDMUND SALVAGE CO. **BARRINGTON, N. J.**

1950 EDITION

A. H. T. CO. CATALOGUE



Facsimile of catalogue, size 8½ × 10¾ × 2½ inches.

SPECIAL FEATURES

Most comprehensive assortment of Microchemical Apparatus heretofore offered.

Large assortments of Pyrex, Coors, Kimble and other trade marked lines.

Code word for every item; for economical ordering by teletype, telegraph or cable.

Net and shipping weights; for convenience in estimating shipping charges.

Air service rates and other information.

The 1472-page edition of our general catalogue LABORATORY APPARATUS AND REAGENTS, published in 1950, illustrates and describes over 15,000 Apparatus items, together with 6,000 Reagent items, all selected primarily for use in laboratories of Chemistry and Biology and, under normal conditions, *carried in stock for immediate shipment.* The many new items include a comprehensive assortment for use in Microchemistry.

In addition to a code word adjacent to each item—for economical ordering by teletype, telegraph or cable—the new edition includes net and shipping weights for convenience in estimating shipping charges, with particular reference to air service.

When requesting copies of this catalogue, scientists will greatly oblige us by a full statement as to their professional connection with organized laboratory work, and purchasing officers by information as to final dispositon of the catalogue, i.e., in the purchasing office or in the laboratory.

We welcome suggestions from those in authority as to the number of catalogues required for convenient use in any laboratory, department, institution or establishment. Such cooperation aids us in making adequate distribution without unnecessary duplication.

ARTHUR H. THOMAS COMPANY

RETAIL—WHOLESALE—EXPORT

LABORATORY APPARATUS AND REAGENTS

WEST WASHINGTON SQUARE PHILADELPHIA 5, PA., U. S. A.

Cable Address, "BALANCE," Philadelphia

To help you decide WHICH Sanborn recording system will best meet your needs

Sanborn direct writing recording systems provide immediately visible, inkless, permanent records in true rectangular coordinates. Above right: Single channel VISO-CARDIETTE. Opposite: Four-channel POLY-VISO CARDIETTE. Below: Two-channel TWIN-VISO CARDIETTE.

BECAUSE the need for registration of various physiological phenomena—either singly, or simultaneously in twos, threes, or fours—varies greatly among the different groups engaged in diagnosis, research, or teaching, Sanborn makes available several recording systems, three of which are shown and identified at the right.

To help you select the equipment best suited to your needs (or budget), Sanborn Company has prepared the above chart which clearly shows the scope or applicability of each Sanborn recording system. Listed under each instrument are phenomena which are illustrative of the fields in which the equipment may be used. Supplementary equipment or attachments, where needed, are indicated and briefly described.

The folder also points out and describes how the ready interchangeability of amplifiers and preamplifiers in the Twin- and Poly-Viso makes possible a wide range of recording possibilities. Other factors, such as paper travel speeds, are charted for ready reference. We will gladly send you a copy of this Applicability Chart or discuss with you further how Sanborn equipment can best fit into your recording picture. Simply address

SANBORN COMPANY

Fine diagnostic instruments since 1917

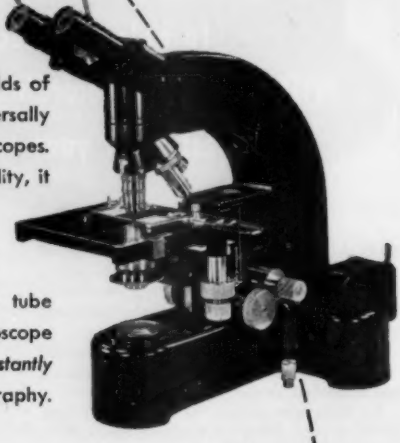
CAMBRIDGE 39, MASSACHUSETTS

OFFICES IN 31 CITIES THROUGHOUT THE U. S. A.

Exclusive combination monocular-binocular tube for photography

Leitz ORTHOLUX

the STAR among research microscopes



Now helping to chart new frontiers in all fields of scientific research, the Leitz *Ortholux* is universally recognized as the ultimate in research microscopes. In addition to outstanding precision and quality, it gives you all the features needed for easier, less tiring microscopic observation. To make the *Ortholux* even *more* useful, Leitz now offers a combination monocular-binocular tube which enables you to photograph the microscope image without changing tubes. You change *instantly* from microscopic observation to photomicrography.

All yours in one outstanding instrument—

Built-in illumination system for transmitted or incident light

Berek double-diaphragm condenser

Large, square built-in mechanical stage with *low set* drive

Low set* micrometer fine adjustment on *double ball bearings

Counter-balanced coarse focusing

Another of the famous Leitz Polarizing Microscopes . . . recognized everywhere as the finest microscopes produced anywhere since 1849.

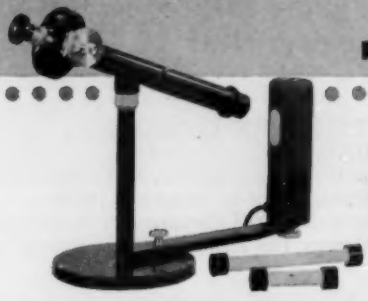
For further information write Dept. 104SC.

E. LEITZ, Inc., 304 Hudson St., New York 13, N. Y.

LEITZ MICROSCOPES • SCIENTIFIC INSTRUMENTS • BINOCULARS
LEICA CAMERAS AND ACCESSORIES

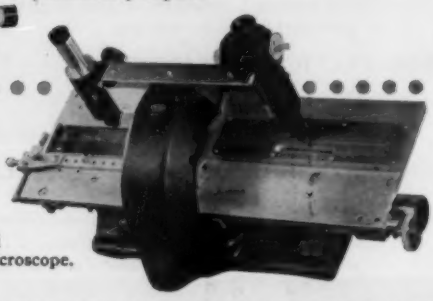
Now Available... from CARL ZEISS JENA

PRECISION
RESEARCH INSTRUMENTS



CIRCLE POLARIMETER
On Vertical Stand

A new model, streamlined, more conveniently arranged for observation. The light source is permanently aligned.



ABBE COMPARATOR

For the maximum precision measurement of length. Equipped with the renowned Archimedean spiral microscope.

CITOPLAST STEREOSCOPIC DISSECTING MICROSCOPE

A new model of an instrument originally introduced by Carl Zeiss several years ago. Built-in quintuple magnification changer. Unusually long, 4-inch viewing distance remains constant for all magnification from 4x to 100x. Large field of view. Unique, laterally and vertically adjustable illuminator for incident and transmitted light.

LUMIPAN MICROSCOPE

A distinguished research microscope fulfilling the most critical requirements. Built-in light source, triple condenser turrent and pancratic illuminating system. The ideal instrument for phase contrast microscopy.

The instruments above represent only a small part of the extensive line of Zeiss microscopes and other precision instruments now available for immediate delivery. Why not write us outlining your particular needs. Our research department will be happy to assist you!

- Microscopes
- Photomicrographic Equipment
- Refractometers
- Polarimeters
- Photometers
- Interferometers
- Projection Apparatus
- Operating Room Illuminators
- Ophthalmological Instruments
- Precision measuring instruments for engineering and industrial purposes.

Exclusive American Agents for Carl Zeiss, Jena, Instruments

ERCONA CORPORATION

Scientific Instrument Division E • 527 Fifth Ave., New York 17, N. Y.

Just Published!

STYRENE

By A. L. WARD and W. J. ROBERTS, *Pennsylvania Industrial Chemical Corporation, Chester, Pa.* 6½ × 9¼. 132 pages, 8 illus., 15 tables, $3.50
(This is the most recent monograph in the series, MONOMERS)

SYNTHETIC METHODS OF ORGANIC CHEMISTRY

By W. THEILHEIMER
Volume V (In English): 1951. 560 pages. Approximately $14.00

SIX-MEMBERED HETEROCYCLIC NITROGEN COMPOUNDS WITH FOUR CONDENSED RINGS.

By C. F. H. ALLEN, *Eastman Kodak Company, Rochester, N. Y.* 1951. 358 pages, 7 illus., 40 tables. $10.00. Special price to subscribers, $9.00
This is the second monograph in the series, "The Chemistry of Heterocyclic Compounds", edited by Arnold Weissberger. This series will be complete in approximately thirty volumes.

THE PECTIC SUBSTANCES

By Z. I. KERTESZ, *New York State Agricultural Experiment Station, Cornell University, Geneva, N. Y.*
1951. 6 × 9. 640 pages, 46 illus., 66 tables. $13.50

ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY
Complete in 12 Volumes

Edited by RAYMOND E. KIRK, *Head, Department of Chemistry, Polytechnic Institute of Brooklyn* and DONALD F. OTHMER, *Head, Department of Chemical Engineering Polytechnic Institute of Brooklyn.*
Assistant Editors: Janet D. Scott and Anthony Standen

Just Published! **Volume 7: FURNACES TO IOLITE**

Volumes appear at 7 month intervals. Each volume approximately 960 pages. 7 3/8 × 10 3/8. With numerous illustrations and tables. Subscription price $25.00 per volume.

THE CHEMISTRY AND TECHNOLOGY OF FOOD AND FOOD PRODUCTS

Second completely revised and augmented edition in three volumes.
Edited by MORRIS B. JACOBS, *Adjunct Professor of Chemical Engineering, Polytechnic Institute of Brooklyn, New York*
Volume I: 1951. 6 × 9. 858 pages, 78 illus., 110 tables. $12.00
Volume II: 6 × 9. 964 pages, 54 illus., 397 tables. $15.00
Volume III: In active preparation.

X-RAY ANALYSIS OF CRYSTALS

By J. M. BIJVOET, N. H. KOLKMEIJER, *Utrecht*, and C. H. MacGILLAVRY, *Amsterdam*. Translated from the 2nd Dutch edition. 1951. 5½ × 8¼. 310 pages, 160 illus., 80 photographs. $6.50

All books available on approval.
Detailed description on request.
Write for our latest catalog. 1951

INTERSCIENCE PUBLISHERS, INC.

250 FIFTH AVENUE, NEW YORK 1, N. Y.

The new Menlo Fluoretor makes possible daylight fluorescence studies—comparisons.

Used world-wide in laboratory, field and factory.

Exclusive dark chamber holds comparison test tubes, solid samples, powders, fluids, etc. Neoprene viewing cone accessory excludes surrounding light for examining large surfaces.

Choice of interchangeable, filtered ultraviolet frequencies-2537 or 3650-63 angstroms. Standardized, hi-output, mercury vapor discharge tube. Instant starting, trouble free. Compact, Portable. Weighs less than 2 lbs. ready to use. Models for battery or line operation.

Write for free brochure and data on use of U-V in your field.

MENLO RESEARCH LABORATORY

Drawer A-11, Box 522, Menlo Park, Calif.

Dealer Inquiries Invited

CAMBRIDGE VERNIER TYPE POTENTIOMETERS

A PRACTICAL AND CONVENIENT INSTRUMENT FOR WORK OF EXTREME PRECISION

The potential is selected by 3 dials, and a $\frac{1}{10}$ range switch gives reading down to 1 microvolt. The accuracy is to 0.00002 volt at maximum reading on the normal range; inter-range accuracy is 0.001 per cent. Standardizing may be carried out on either range without altering the dial settings. The switches and coils can be immersed in oil to minimize thermal e.m.fs.

Send for complete information

CAMBRIDGE INSTRUMENT CO., INC.

3748 Grand Central Terminal, New York 17, N. Y.

PIONEER MANUFACTURERS OF PRECISION INSTRUMENTS

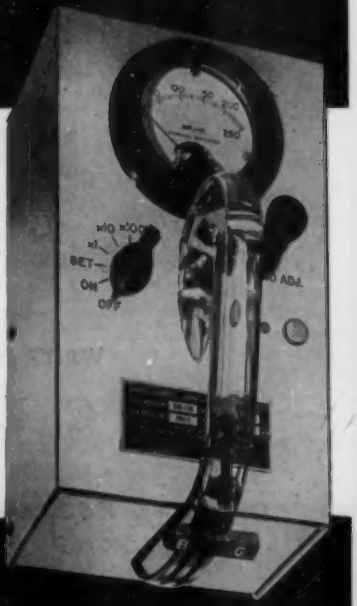
Instruments for Nuclear Research by Technical Associates

JUNO SURVEY METER

Models SRJ-1 and HRJ-1

- **Measures alpha, beta, and gamma radiation.**
- **3 sensitivity ranges.**
- **Portable, lightweight, battery-operated.**
- **Meets A.E.C. specifications.**

The Juno Survey Meter measures the intensity of, and distinguishes between alpha, beta, and gamma radiation. Its use protects personnel from over-exposure to radioactivity and X-rays. Two models are available: SRJ-1 for standard range (50, 500, and 5000 MR/HR full scale). HRJ-1 for high range (250, 2500, and 25,000 MR/HR full scale). For complete details, write for Bulletin No. 125.



Our new Isotope Department offers "tagged" compounds, film badge service, and radiation sources for medical, industrial, and basic research applications. Inquiries invited.

TECHNICAL ASSOCIATES

3730 San Fernando Road, Glendale 4, Calif.

"Announcing"

the Newly Developed

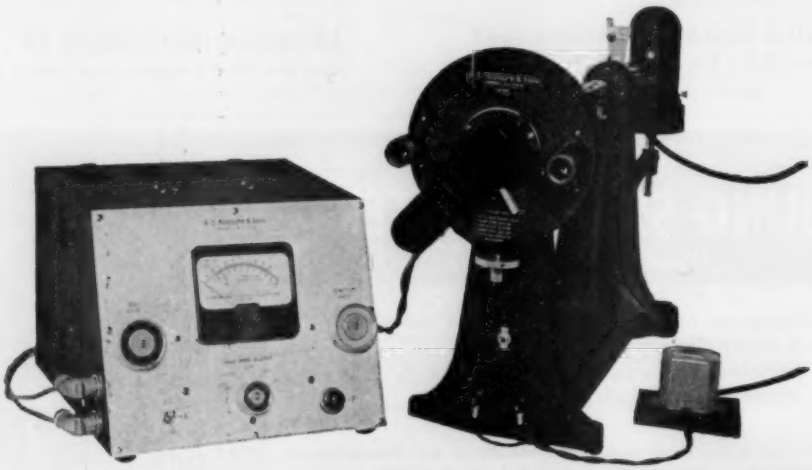
RUDOLPH

PHOTOELECTRIC POLARIMETER

— AFFORDS GREATER PRECISION —

— ELIMINATES EYE FATIGUE — SAVES TIME —

PHOTOELECTRIC UNIT IS ADAPTABLE TO MOST VISUAL POLARIMETERS OF OUR OWN AND OTHER MANUFACTURE



WRITE FOR FURTHER INFORMATION TO

O. C. RUDOLPH & SONS

Manufacturers of

OPTICAL RESEARCH AND CONTROL INSTRUMENTS

P. O. BOX 446 CALDWELL, N. J.

Size 1 Model SBV Size 2 Model V

Two New Centrifuge Models

THE New International Size 1 Model SBV and Size 2 Model V Centrifuges embody the many time-proven features found in their predecessors — the Size 1 Type SB and Size 2 machines — and in addition incorporate important engineering improvements. A transformer-type speed controller replaces the resistance rheostat heretofore used and the Centrifuges are now shipped to you mounted on a permanently attached sub-base equipped with casters.

Speed Controller

Stepless, uniform speed control throughout the entire range is achieved and troublesome heating of — and heat radiation from — the controller is eliminated. Controller and two-hour automatic timer are mounted in an attractive enclosing cabinet conveniently located on the side of the Centrifuge steel guard.

Sub-Base Mounting

No assembly of any kind is necessary. No separate portable stand to bother with. Simply uncrate the completely assembled unit, wheel it to the electric outlet and plug it in. Specially designed vibration dampeners, incorporated in the sub-base, provide maximum absorption of horizontal and vertical vibration and prevent their transmission to the floor of the laboratory.

Accessories

All interchangeable heads, shields, cups, and attachments listed for the discontinued SB and Size 2 machines fit the new models. Thus the Model SBV and Model 2V offer the same versatility and adaptability to your requirements. Send today for descriptive Bulletins V-1 and V-2 containing complete details.

INTERNATIONAL EQUIPMENT COMPANY

1284 SOLDIERS FIELD ROAD, BOSTON 35, MASS.

MACMILLAN

Among the new MACMILLAN books

The Astronomical Universe

Wasley S. Krogdahl, *Northwestern University*

Here is a college text in introductory astronomy, specifically written for those general students who elect a course in astronomy to meet a science requirement or to supply elective credits. Dr. Krogdahl's text describes simply, clearly, and fully what is known of the contents, behavior, and history of the astronomical universe and of the scientific procedure by which such knowledge is acquired. *Ready in November–December.*

The Principles of General Biology

Mary S. Gardiner, *Bryn Mawr College*

A principles type book rather than a descriptive statement of factual material, this text presents a broad general review of the principles underlying biological concepts and methods. Section I deals with the physical and chemical bases of biological structures and operations; Section II with the relationship of living things to the physical world and the organization of biological types; Secton III with the functioning of biological systems. *Ready in November–December.*

Taxonomy of Vascular Plants

George H. M. Lawrence, *Cornell University*

Providing in one volume a comprehensive source of information on the theory, principles and operating procedures followed in plant taxonomy, this text accounts for all of the families of plants known to grow in North America north of Mexico. Dr. Lawrence was a delegate on nomenclatorial matters to the Seventh International Botanical Congress in Stockholm and revisions in the International Rules of Botanical Nomenclature which were made at the Congress are incorporated into this text. *Published September 25.*

THE MACMILLAN COMPANY

60 FIFTH AVENUE, NEW YORK 11, NEW YORK

THE EASIEST WAY... of Projecting Lecture Material Ever Devised!

VACUMATIC PLATEN*

Beseler's revolutionary FEED-O-MATIC* feature on the new VU-LYTE Opaque Projector permits continuous, smooth projection of mounted or unmounted material.

Think of it! You simply feed your lecture material *as is* onto the metal conveyor belt of the FEED-O-MATIC, and advance it into projection position by turning a handle. There is no special need to mount copy, or insert it into holders—because the unique platen of this ultra-modern projector holds *all* copy material *absolutely flat.*

POINTEX† PROJECTION POINTER

You can feed mixed or continuous copy through evenly, and without light flashes—since the platen is not raised or lowered. A full 8½x11 page or a postage stamp are projected with equal ease. There is no curl or flutter. As new copy is fed in at the left side of the projector, preceding copy is ejected from the right side. Thus you obtain uninterrupted projection—which aids tremendously in the efficient presentation of mixed copy, and proves eminently suitable for continuous copy in scroll form.

The FEED-O-MATIC CONVEYOR is one of the exclusive Beseler developments that make the VU-LYTE the easiest opaque projector in the world to use—ideal for schools, churches, clubs, and business. And there are many other outstanding VU-LYTE features that team to help you obtain peak performance with maximum ease.

1. YOU CAN use the VU-LYTE in a partially-lighted room. Total darkness is not necessary in order to obtain clear, sharp images and brilliant colors—because VU-LYTE provides extra illumination.

2. YOU CAN use copy "as is"—without mounting or inserting into holders. The unique Beseler VACUMATIC PLATEN* holds all copy absolutely flat during projection. A full 8½x11 page letter or a postage stamp can be projected with equal ease, without curl or flutter.

3. YOU CAN project a lighted arrow onto any part of the illustration by means of the new Beseler built-in POINTEX † POINTER—thereby pointing out details without leaving the projector.

4. YOU CAN use VU-LYTE on an uneven surface—project on small or large screens. In addition, VU-LYTE is an amazingly quiet and cool operating projector.

*Pat. Pend
†Patented

These advanced, exclusive features, plus others, are incorporated in a projector that weighs only 35 lbs. and is **REDUCED IN PRICE.**

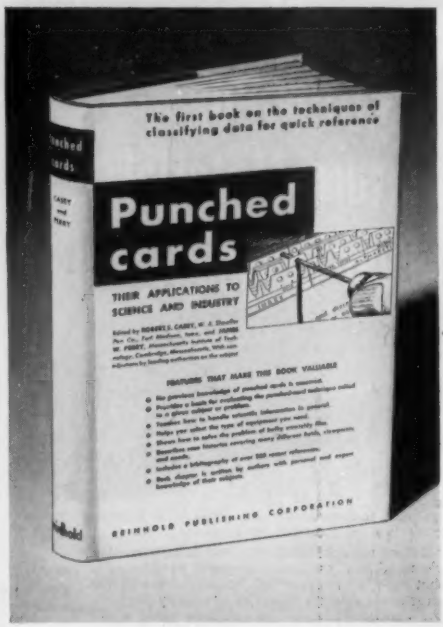
Ask for *free demonstration* of the precision-built VU-LYTE in your *own projection room.* And for more information regarding this truly new concept in opaque projection, ask for booklet—B.

CHARLES Beseler COMPANY
EST. 1909
60 Badger Avenue, Newark 8, N. J.
The World's Largest Manufacturer of Opaque Projection Equipment

CHEMISTRY • CHEMICAL ENGINEERING • MATERIALS ENGINEERING • METALLURGY • PHYSICS

REINHOLD BOOKS

PHYSICS • METALLURGY • MATERIALS ENGINEERING • CHEMICAL ENGINEERING • CHEMISTRY


The first book on the techniques of classifying data for quick reference
Punched cards
THEIR APPLICATIONS TO SCIENCE AND INDUSTRY
REINHOLD PUBLISHING CORPORATION

PUNCHED CARDS

Their Application to Science and Industry

By **ROBERT S. CASEY**, *W. A. Schaeffer Pen Co., and* **JAMES W. PERRY**, *The Massachusetts Institute of Technology*

Instruction and help for large and small card files on any subject.

As masses of data multiply, punched cards are being applied effectively as filing systems in many scientific, industrial and business fields. No other system offers so effective and foolproof a means of searching through quantities of information and isolating exactly the information that is wanted.

This new book covers files of all sizes, from a few hundred cards to many thousands, and tells how to arrange and expand any card file. It describes all card-filing equipment currently in use. It makes existing experience and methods available to all those who deal with scientific and technical information and who must find out quickly what they want to know.

1951 *516 pages* *$10.00*

LABORATORY DESIGN

Edited by
H. S. COLEMAN, *Mellon Institute*

The latest report of the Committee on Design, Construction and Equipment of Laboratories of the National Research Council. Covers materials, services, facilities and equipment; teaching laboratories; industrial laboratories; describes various types of modern laboratories.

393 pages 9" × 12", illustrated
1951 *$12.00*

ALKALI SOILS

Their Formation, Properties and Reclamation

By **WALTER P. KELLEY**, *formerly of the University of California*

ACS Monograph No. 111

Provides a new basis for dealing with the alkali soil problem

Covers the causes of alkali soil formation in terms of ion exchange—a field in which Dr. Kelley is renowned. The basic researches of Hilgard and Gedroyz are discussed in great detail and all the pertinent evidence is presented and evaluated.

ACS Monograph, 168 pages
1951 *$5.00*

MARINE PRODUCTS OF COMMERCE

New 2nd Edition; Revised Enlarged

Their Acquisition, Handling, Biological Aspects and the Science and Technology of Their Preparation and Preservation

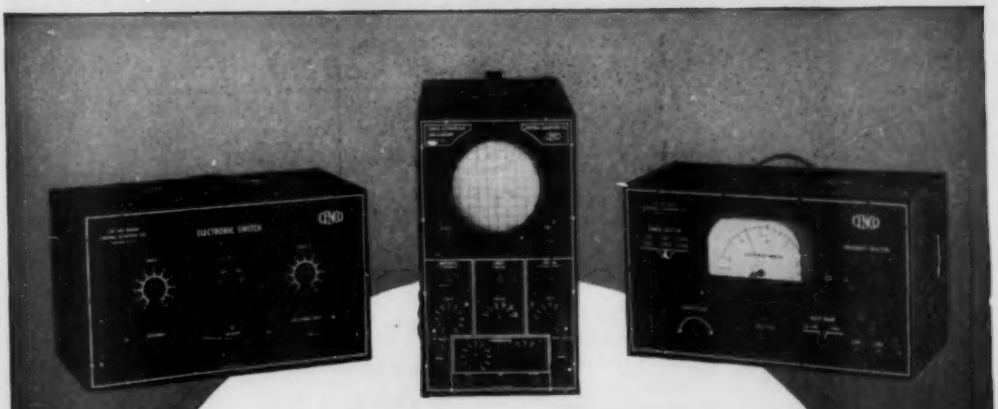
By **DONALD K. TRESSLER**, *Quartermaster Food and Container Institute, and* **JAMES McW. LEMON**, *U. S. Department of Interior*

An enormous amount of descriptive information and reference data concerning all commercially important products of the sea—fish, seaweed products, salt, chemicals, etc. A condensation of many treatises on oceanography, chemical technology, statistics, nutrition, gemology and other subjects.

800 pages, profusely illustrated
1951 *$18.00*

SEND FOR COPIES ON APPROVAL

reinhold *publishing corporation*
DEPT. M-299 330 WEST 42ND STREET, NEW YORK 18, N. Y.



The CENCO SINE WAVE AND SQUARE WAVE GENERATOR will produce both sine waves and square waves in the frequency range from 20–20,000 cps. This range is obtained in three steps selected by means of a range switch on the front panel of the instrument. The three ranges are from 20–200 cps., 200–2000 cps. and 2000–20,000 cps. The oscillator is calibrated with an accuracy of ±3% of the setting, or 3 cps.

The CENCO ELECTRONIC SWITCH permits the simultaneous observation of two or more separate signals on the screen of a cathode ray oscilloscope. A signal electronic switch will allow two signals to be observed, while if two electronic switches are connected in cascade, three signals may be observed with but one oscilloscope. The electronic switch may be used to observe the input signal to an amplifier and the output signal from the same amplifier simultaneously on the same oscilloscope. Thus, wave form, amplitude and phase distortion of the amplifier may be quickly examined. The effects of added components to circuits, differentiation and integration of a square wave, and many other phenomena may be seen.

No. 80592 Cenco Sine Wave and Square Wave Audio Oscillator . . Each $130.00
No. 80600 Electronic Switch Each $105.00
No. 71552 Cenco Cathode Ray Oscilloscope, 5-inch screen . . . . . Each $165.00

Write for circular

CENTRAL SCIENTIFIC COMPANY

Scientific CENCO *Apparatus*

1700 IRVING PARK ROAD CHICAGO 13

NEW YORK BOSTON SAN FRANCISCO NEWARK LOS ANGELES TORONTO MONTREAL

Coming Soon From the **MOSBY** *Press!*

Hoskins—Bevelander **New Second Edition**

ESSENTIALS OF HISTOLOGY

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

The first edition of ESSENTIALS OF HISTOLOGY is now something of a legend in the schools where it is used—for it truly lived up to its title and its purpose. It actually presented the most important morphological characteristics of the tissues and organs in simple and systematic form—and teachers searching for a text to be used in a short course found it here.

In this, the new Second Edition, it has been brought up to date with many advantageous changes. It makes clear what features are to be seen in ordinary preparations, what points require special techniques for demonstration, and what is to be accepted as a result of investigation outside the scope of an elementary course.

Most of the illustrations are original drawings which help the student build a solid foundation in histological study.

The text continues to cover the facts which a beginning student should have readily available before he undertakes the study of each tissue or organ.

Comments from teachers using the First Edition:

"The book, "Essentials of Histology," is ideal for my course in which we attempt to introduce histology."

S. W. F., Instructor, College of Pharmacy
University of Florida

"Just right for a semester, two credit course; material is complete without being verbose, illustrations are excellent."

I. L. R., University of Nevada

"This test though brief states the fundamentals clearly yet concisely. It gives the instructor a firm foundation on which to spread herself. The excellent diagrams are of great value."

C. C., Pacific Lutheran College

"A very excellent book, confining itself purely to the essentials as the title indicates. Nothing of an extraneous nature is included."

A. O., University of California
College of Pharmacy

By MARGARET M. HOSKINS, Ph.D., and GERRIT BEVELANDER, Ph.D.
New York University

(In Preparation—definite publication date
will be announced as soon as possible.)

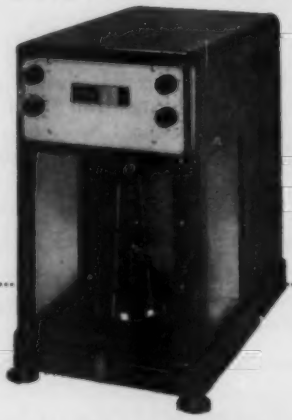
Direct inquiries for consideration as class text and orders to 3207 Washington Blvd., St. Louis 3, Missouri

PUBLISHED BY—*The* **C. V. MOSBY** *Company*
SCIENTIFIC PUBLICATIONS
Saint Louis • San Francisco • New York

FOR AMERICA'S LABORATORIES...

A New, Completely Direct-Reading Analytical Balance...

THE *Gram-atic* BALANCE



. . . weighs in one-third the time required by the usual balance.

Its control knobs are manipulated to select built-in weights. Corresponding figures appear on the direct reading scale.

Weights under 100 milligrams are indicated automatically.

The Gram-atic Balance weighs samples up to 200 grams and has constant sensitivity throughout this entire range.

For 115 and 230 volt 50-60 cycle A. C. . . . . **$895.00 each.**

Fast (20 second weighing)
Eliminates all weight handling
Beam under constant load
One-scale reading
Constant sensitivity
Weighs below 100 milligrams automatically

Entire weight of sample is read on direct-reading indicator.

Write for Folder No. 4G

Headquarters for Laboratory Supplies

FISHER SCIENTIFIC COMPANY

PITTSBURGH 717 Forbes (19) • **NEW YORK** 635 Greenwich (14) • **WASHINGTON** 7722 Woodbury (Silver Spring, Md.) • **ST. LOUIS** 2850 S. Jefferson (18) • **MONTREAL** 904 St. James

McGRAW-HILL • • Items of

SOUND MOTION PICTURES on COLLEGE PHYSICS

Brief, 16 mm films made in collaboration with the American Association of Physics Teachers render complicated physical processes completely understandable. Each film is a complete unit executed entirely in animation. All narration is brief and to the point.

Uniform Circular Motion 6¼ min.
The Gasoline Engine (Otto Cycle) 6 min.

For complete details on these and forthcoming titles write to the Text-Film Department for Folder CPF.

THE THEORY AND PRACTICE OF INDUSTRIAL RESEARCH

By DAVID BENDEL HERTZ, Columbia University. *The McGraw-Hill Engineering Management Series.* 385 pages, $5.50

This important text deals with the process of research as it applies to industry, covers the fundamental requirements of research operations, and shows how the organization and structure, which may be most profitably utilized, follow from an analysis of the elements in the process. Designed to assist management in arriving at a sound policy with regard to project selection and research administration in objectively scrutinizing proposals and the progress of its own work.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH

By C. E. KENNETH MEES and JOHN A. LEERMAKERS, Eastman Kodak Company. Second Edition. 383 pages, $5.00

Covering all the steps in the organization and operation of an industrial research laboratory, this text deals with the nature of industrial research and its effect on the economy and describes the setup of such agencies as government laboratories, research associations, and technological research institutes. A valuable guide for both student and practitioner to the effective solution of organizational and operational problems associated with research departments.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Radiation Laboratory Series

Now complete, with the recent publication of its final volume, this outstanding series is already in wide use as texts and reference works in colleges throughout the country. They have become a primary source for information concerning radar, electronics and high frequency techniques. Based upon information accumulated during the war in the field of microwave radar, the subject matter has been so treated that its applicability includes virtually all the fields of electronics: television, communication, industrial instrumentation and control, research in the biological and physical sciences, and related fields.

Interest to Science Readers

SAMPLING INSPECTION BY VARIABLES

By ALBERT H. BOWKER and HENRY P. GOODE, Stanford University. Ready in January

Presents a comprehensive set of sampling plans for use when the inspection of the item is by variables and when the lot is to be evaluated in terms of its precentage defective. These plans can be used by industrial and business concerns for acceptance sampling inspection of purchased goods, parts and raw materials; for sampling inspection of goods within a concern; and for sampling inspection of outgoing products.

DICTIONARIES

GERMAN–ENGLISH TECHNICAL AND ENGINEERING DICTIONARY
928 pages, $20.00

FRENCH–ENGLISH SCIENCE DICTIONARY. New 2nd Edition
Ready in October

GERMAN–ENGLISH SCIENCE DICTIONARY
Second Edition, 562 pages, $5.50

GERMAN–ENGLISH MEDICAL DICTIONARY
In press

NATIONAL NUCLEAR ENERGY SERIES

With the imminent publication of *Physical Properties and Analysis of Heavy Water* by Kirshenbaum, Murphy, and Urey, *Biological Effects of External Beta Radiation* by Zirkle, and *Theory of Isotope Separation* by Cohen, the National Nuclear Energy Series will reach a total of twenty-one published titles under the eight divisions of the Manhattan Project Technical Section. For further information on this series, write the McGraw-Hill Book Company for latest bulletins.

PRINCIPLES OF QUANTUM MECHANICS

By W. V. HOUSTON, President, Rice Institute, Texas. *International Series in Pure and Applied Physics.* Ready in December

Contains a deductive presentation of the wave mechanics form of quantum mechanics which should enable the student to understand the basic principles involved. A general outline of basic theory developed from two fundamental postulates is followed by a series of illustrative applications. These applications introduce the various fields to which non-relativistic quantum mechanics can be applied.

Send for copies on approval

McGRAW-HILL BOOK COMPANY, INC.
330 West 42nd Street **New York 18, N. Y.**

NEW SPEED . . . NEW ACCURACY . . . NEW CONVENIENCE . . .

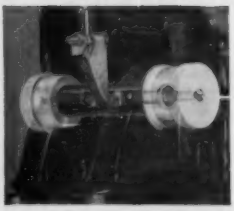
New!

BAUSCH & LOMB

Dynoptic

LABROSCOPES

The World's finest line of laboratory microscopes . . . sets higher standards for microscopy with *entirely new* "Years Ahead" design features.



Low Position *Dua-rol* Ball-Bearing and Roller Fine Adjustment—for critical focus, faster and easier; longer life; non-tiring manipulation.

Mechanical Stage with Low Position Controls for comfortable operation; *Vacu-trol* Slide Holder secures and positions slides gently and firmly.

Roto-sphere Ball-Bearing Nosepiece—More accurate centration, longer life, smoother travel.

Opti-lume Integral Illuminator—Instantly removable; well ventilated; standard 15-watt, 115-volt lamp.

Plus many other new and service-proved Bausch & Lomb advantages

Write for a demonstration and for complete information on this new line of microscopes. Bausch & Lomb Optical Co., 642-14 St. Paul St., Rochester 2, N. Y.

CLIP AND MAIL THIS COUPON TODAY

BAUSCH & LOMB OPTICAL CO.
642-14 ST. PAUL ST., ROCHESTER 2, N.Y.

Please send me complete information on the new B&L *Dynoptic* Labroscopes.

☐ I would like a demonstration.

NAME_____

SCHOOL OR FIRM_____

ADDRESS_____

CITY_____ STATE_____

Chemical Analysis by Neutron Spectroscopy[1]

T. I. Taylor, Robert H. Anderson, and W. W. Havens, Jr.

Chemistry and Physics Departments, Columbia University, New York

DURING RECENT YEARS the neutron has served as a very useful tool for the study of certain nuclear and atomic properties of matter (*1*). Neutrons are now finding a number of important applications to the determination of the composition of materials (*2*). A review of the properties and interactions of neutrons (Table 1) shows that chemical analysis by neutron interactions is possible by several different methods.

TABLE 1

SUMMARY OF PROPERTIES AND INTERACTIONS OF NEUTRONS

General	Mass, 1.00893; charge, 0; spin, $\pm$ ½; half-life, 10–20 min; statistics, Fermi-Dirac.
Production	See Table 2.
Wave properties	$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$ $\lambda(A) = \frac{3.96 \times 10^3}{v} = \frac{0.286}{\sqrt{E(ev)}}$ where h = Planck's constant, m = mass in grams, v = velocity in m/sec = $1.383 \times 10^4 \sqrt{E(ev)}$, E = kinetic energy = ½ mv^2; $E(ev)$ = kinetic energy in electron volts; λ = wavelength.
Diffraction by crystals	At $E = 1$ ev, $\lambda = 0.286$ A; at $E = 0.026$ ev, $\lambda = 1.8$A: Wavelength in this energy range is of the order of distance between atomic planes in crystals. Bragg diffraction occurs: $n\lambda = 2d \sin\theta$ where n = order of reflection, d = distance between atomic planes, and θ = angle of incidence with plane of atoms.
Interaction with matter	Pass through matter much more readily than charged particles do. Practically no ionization produced. Fast neutrons knock protons from hydrogen-containing material. Prolonged irradiation may change color, thermal conductivity, or electrical conductivity. Bonds may be broken with decomposition of molecules. Due to their magnetic moment, slow neutrons interact with electron magnetic moment of paramagnetic and ferromagnetic atoms.
Detection	Fast neutrons: Recoil protons and nuclear reactions. Example: $Si^{28}(n,p)Al^{28} \xrightarrow[2.3 \text{ min}, 3.0 \text{ mev}]{\beta^-} Si^{28}$

[1] From a paper presented at the Gordon Conference on Instrumentation, Aug. 1951, and from a general review by the authors in *Nucleonics* (*3*). This work was supported in part by the Atomic Energy Commission, Project AT(30-1) Gen 72.

SUMMARY OF PROPERTIES AND INTERACTIONS OF NEUTRONS—(*Continued*)

	Slow neutrons: Radioactivation of foils of In, Mn, Au, Ag, Rh, etc. Example: $Mn^{55}(n,\gamma)Mn^{56} \xrightarrow[1.59\ h,\ 2.8 \text{ mev}]{\beta^-} Fe^{56}$ Counters lined with B or Li, or proportional counters filled with $B^{10}F_3$. Example: $B^{10} + n \rightarrow Li^7 + \alpha$ $Li^6 + n \rightarrow H^3 + \alpha$ Fission Example: $U^{235} + n \rightarrow$ high energy fission fragments. Photographic plates containing elements that become radioactive by interaction with neutrons. Scintillation counters arranged to detect γ-rays emitted when neutrons are absorbed or to detect other nuclear reactions caused by neutrons.
Scattering process (n,n) reactions	Elastic nuclear scattering; inelastic nuclear scattering; resonant nuclear scattering; coherent crystal scattering (diffraction); ferromagnetic scattering; paramagnetic scattering; inelastic molecular scattering; neutron-electron scattering.
Absorption process	The neutron is retained by nucleus and a photon or other particle is emitted: (n,γ), (n,p), (n,α). Also $(n,2n)$ and $(n,\text{fission})$.

Probably the most important and the most widely used method of analysis with neutrons at the present time is that of radioactivation (*3*). Isotope-dilution methods using neutron-produced radioactive isotopes have also proved valuable as a tool for analytical chemistry (*4*). Neutron diffraction (*5*) has supplemented x-ray and electron diffraction in the determination of the structure of an increasing number of substances. Since reviews of the above applications of neutrons to problems in chemistry are already available, this paper will be primarily concerned with those applications that involve the absorption and scattering of a beam of neutrons. In particular, emphasis will be placed upon the change in neutron interactions as a function of their energy or wavelength, as is done in optical spectroscopy.

Neutron Sources

One of the most important factors involved in the application of neutrons to problems of chemical analysis is the availability of suitable neutron sources. In Table 2 the slow neutron flux obtainable from a number of sources is summarized (*6*). It is to be hoped that future developments will provide the chemist with small laboratory machines for the pro-

TABLE 2

NEUTRON SOURCES

Source	Approximate neutron intensity
Chain-reacting piles	
Fission: U^{235} (n, f)	10^{10} to 10^{14} n/cm^2 – sec
Particle accelerators	
Cyclotron: Be^9 (d, n) B^{10}	10^{12} n/sec
Van de Graaf or Cockroft-Walton	$10^8 - 10^{10}$ n/sec
H^2 (d, n) He^3	
H^3 (d, n) He^4	
Li^7 (p, n) Be^7	
Electron linear accelerator	10^{14} n/sec (pulsed)
Be^9 (γ, n) Be^8	
Radioactive (typical sources)	
Radium-beryllium:	
Be^9 (α, n) C^{12}	1.3×10^7 n/Curie-sec
Polonium-beryllium:	
Be^9 (α, n) C^{12}	2.8×10^6 n/Curie-sec
Photoneutron sources:	
Sb^{124} $Be(\gamma, n)$	3.2×10^6 n/Curie-sec

duction of high-intensity neutron sources for certain types of chemical problems.

In practically all sources, the neutrons are liberated at rather high energies (0.1 mev–10 mev) as a result of the nuclear reactions listed in Table 2. Usually, slow neutrons are required for applications to chemical analysis; consequently the fast neutrons must be slowed down. This is done by allowing them to pass through layers of materials containing certain of the lighter elements such as hydrogen (in paraffin or water), beryllium, or carbon. The slowing down results from a billiard-ball–type of collision in which the neutrons lose a part of their kinetic energy to the light element, cascading in a short time to lower energies. A 1-mev neutron, for example, will be slowed down to the thermal energies (0.026 ev) of molecules, on the average, in about 18 collisions with H, 80 with He, 110 with C, and over 2,000 with Pb or U. About 5 cm of paraffin is sufficient for slowing down the fast neutrons.

The result of the slowing-down process is a flux of slow neutrons that diffuses through the material and emerges with an energy distribution corresponding approximately to the Maxwell-Boltzman distribution for a temperature somewhat higher than the temperature of the slowing-down material. A high-energy component that varies with the source of the neutrons is also present. A typical energy or wavelength distribution of slow neutrons produced in this way is illustrated in Fig. 1.

In some of the applications that will be described later, slow neutrons with a rather broad energy distribution are useful. However, if the interactions at a particular energy or wavelength are to be used for a chemical analysis, it is necessary to select a narrow energy band by means of suitable spectrometers, velocity selectors, filters, or selective detectors.

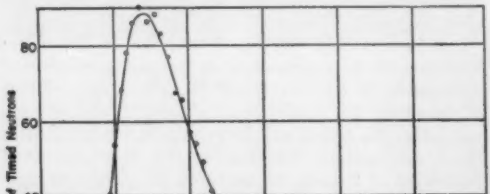


FIG. 1. The slow neutron distribution from a "thick" paraffin source used with the Columbia University cyclotron (6.2-cm thick paraffin in a box of ¼"-thick plywood). Dotted curve follows the experimental points. Solid curve is theoretical for a temperature of 390° K.

NEUTRON SPECTROMETERS

Mechanical velocity selectors. One of the first methods of selecting a narrow energy band of neutrons employed a mechanical velocity selector and was used by Dunning, Pegram, Mitchell, and Segre (*7*) in conjunction with a radium-beryllium source. Other types of mechanical velocity selectors (*8*) have been designed since that time for operation in different regions of the slow neutron distribution curve. The general principle of the mechanical velocity selector, when used as a neutron spectrometer, is illustrated in Fig. 2. It was designed by Fermi and his co-workers

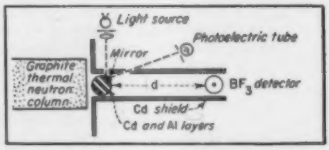


FIG. 2. Schematic diagram of a mechanical velocity selector.

(*8*) for use with the chain-reacting pile. A rotating cylinder of alternate thin laminations of aluminum and cadmium is placed next to the graphite thermal neutron column. Neutrons can pass through the cylinder only when the direction of the layers is parallel to the beam. The mirror rotates with the cylinder, and the reflected light activates the photoelectric tube, which in turn activates the BF_3 neutron counter. By adjusting the position of the mirror, the photoelectric tube and counter can be activated at time t after the neutrons have passed through the cylinder. Thus only those neutrons are counted whose velocity is equal to d/t. An absorber can then be placed in the beam, and the transmission of neutrons through it for this velocity can be measured. The time t can then be changed, and the transmission can be measured at other velocities. This method is useful to about 0.2 ev, where the resolution becomes poor because the speed at which the cylinder can be rotated is limited.

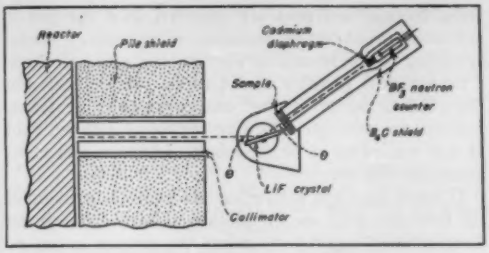


FIG. 3. Schematic diagram of a crystal spectrometer for neutrons.

The mechanical velocity selector designed by Selove (*9*) is useful for the higher energy neutrons (short wavelengths), whereas the one devised by Hughes (*10*) and his co-workers is useful in the lower energy regions (long wavelengths to about 20 A).

Crystal spectrometer. Crystal spectrometers for selection of neutrons of a narrow energy-band or wavelength range are based on the wave properties of neutrons (*11*). The general arrangement of the equipment as illustrated in Fig. 3 is very similar to that used for x-ray spectrometers.

Neutrons from a chain-reacting pile are collimated so that a parallel beam of neutrons hits the surface of a crystal such as lithium fluoride. Maxima in the diffraction pattern occur in such a way that the Bragg relation $n\lambda = (nh)/(mv) = 2d \sin \theta$ is satisfied (Table 1). Neutrons of a given energy can be obtained by setting the crystal and detector at the appropriate angle with respect to the neutron beam. Thus, if the (100) planes of LiF in which $d = 2.005$ A are set such that $\theta = 20$ degrees, then the velocity of the neutrons impinging upon the crystal can be calculated in the following manner for a first-order reflection:

$$v = \frac{n\,h}{m\,2d \sin\theta} = \frac{(1)\,(6.62 \times 10^{-27})}{(1.67 \times 10^{-24})\,(4.01 \times 10^{-8})\,(0.342)}$$
$$= 2.88 \times 10^{5} \text{ cm/sec},$$

which corresponds to an energy in electron volts of

$$E = \frac{\frac{1}{2}\,mv^2}{e} = \frac{(0.5)\,(1.67 \times 10^{-24})\,(2.88 \times 10^{5})^2\,(300)}{4.80 \times 10^{-10}}$$
$$= 0.0430 \text{ ev}$$

or to a wavelength of $\lambda = h/(mv) = 1.38 \times 10^{-8}$ cm, or 1.38 A.

To measure the transmission of a sample at this velocity, the intensity of the beam is measured, first without the sample present and then with the sample between the crystal and the detector. The angle of incidence, θ, can then be changed to obtain the transmission at other neutron energies from 0.01 to 100 ev. At the higher energies the angle of incidence is very small, and at lower energies the higher-order reflections interfere. One important advantage of the crystal spectrometer is that the beam is essentially monoenergetic; that is, the only neutrons that pass through the sample are those that have the energy given by the Bragg equation. Consequently, by measuring the activation of the sample, the cross section of certain isotopes can be determined.

Time-of-flight velocity selector. Block diagrams showing the general principles of the modulated cyclotron velocity selector (*12*) are given in Figs. 4 and 5. By modulating the ion-accelerating potential

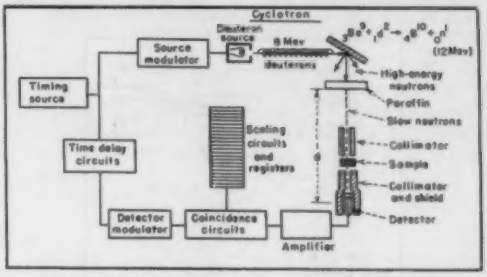


FIG. 4. Block diagram of cyclotron velocity selector.

in the source of a cyclotron, short bursts of deuterons can be made to hit a beryllium target. This produces fast neutrons for short periods of τ μsec (variable from 2 to 1,024 μsec) in the Columbia University neutron spectrometer. After being slowed down in paraffin, they travel toward the detector placed at a distance d (6 m) from the source. The neutrons arriving at the detector after t_1 μsec (except for a small correction for the time necessary to accelerate the deuterons and to slow down the neutrons) are counted for a period of τ' μsec. This period is usually the same as the time of the neutron burst.

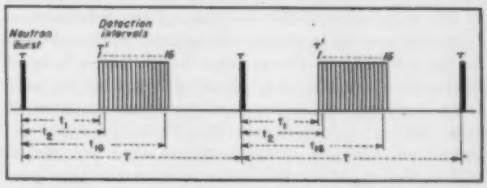


FIG. 5. Principle of the time-of-flight velocity selector.

The time-of-flight of this group of neutrons is then t_1/d μsec/m, or their velocity is d/t_1. At the end of this first detection interval, a second coincidence unit is turned on for τ μsec to count the neutrons arriving after a time of t_2 μsec. In this way, a total of 32 scaling units count the neutrons arriving at the detector during each of the 32 successive detection intervals of τ μsec each.

After a time T—which may be 1,024 μsec, for example—another burst of neutrons is produced, and the neutrons are again counted at each detection interval. The time between bursts can be adjusted in steps from 256 to 32,768 μsec, and the detection may be started at any delay time t_1 after the start of the burst. Also, both the duration of the burst τ and of the detection interval τ' can be varied from 2 to 1,024 μsec. With this system, the number of neutrons arriving at the detector as a function of time can be determined in any desired range of neutron energies from 0.001 to 10,000 ev. The resolution is approxi-

mately triangular and constant for a specified setting of the apparatus, when measured on the time-of-flight basis.

The general arrangement of the cyclotron is shown diagrammatically in Fig. 6. Neutrons emerging from

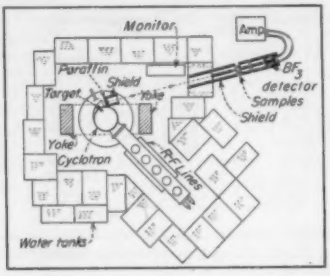


FIG. 6. Geometrical arrangement of cyclotron velocity selector, samples, and detector.

the paraffin source are collimated by thick shields of boron carbide. They then pass through the sample, and into the detector, which consists of a proportional counter 10 cm long and 5.0 cm in diameter, filled with 50 cm of BF_3 enriched in B^{10}. Actually, two channels with associated detectors, circuits, and scaling units are provided. By alternating the container plus sample with an identical empty container between the two channels, duplicate determinations of the transmission can be obtained. An average of the values obtained in this way improves the accuracy of the transmission measurements by reducing the effects of fluctuations in the intensity of the neutron beam. The effects of fluctuations are also minimized by counting the neutrons arriving at the counters for equal amounts of total neutron production rather than for equal intervals of time. A uranium fission-chamber placed within the cyclotron enclosure is used for this purpose. Detailed discussion of the operation of the cyclotron velocity selector is given in papers by Rainwater, Havens, Wu, Dunning, and their associates (*13*).

Resonance detectors and filters. Resonance detectors (*14*) combined with suitable filters may at times be conveniently employed to measure transmissions of samples at the resonance energy of the detector. For example, the transmission of a substance for neutrons with an energy of 1.45 ev (the resonance absorption energy for indium) can be measured using indium foil surrounded by cadmium as a detector. The radioactivity induced in the foil with the sample in the beam, divided by the radioactivity induced in the foil with the sample out of the beam, gives the transmission of the sample at this energy. Other resonance detectors besides indium, such as thin foils of gold, silver, or manganese, etc., can be used.

From the radioactivity induced in the detector foil by the (n, γ) reaction, the intensity of the beam can be calculated, as will be described later. By placing a cadmium filter in front of one of these detector foils, thermal neutrons are removed, and the foil is activated primarily by neutrons of an energy corresponding to the resonance energy of the foil element. This makes it possible to determine the transmission for a rather sharply defined energy group of neutrons. Indium, for example, has a resonance at 1.45 ev, gold at 4.87 ev, iodine at 40 ev, cobalt at 126 ev, and manganese at 335 ev.

If more than one activation resonance is present in the detector, then one or another of the levels can be discriminated against by using the proper boron or cadmium filter. Although this method has certain limitations, it can be useful in determining the transmission at a particular energy when a velocity selector is not available. Cross sections for indium resonance neutrons have been tabulated by Marshall (*15*) and by Hanstein (*16*), and can be used for the determination of composition, as will be described later.

A radium-beryllium source with which these detectors may be used in a laboratory is illustrated in Fig. 7. Neutron sources of this or other types (Table 2) can be arranged for transmission experiments using either the radioactivation of foils or BF_3 counters. Samples can also be introduced for radioactivation analysis.

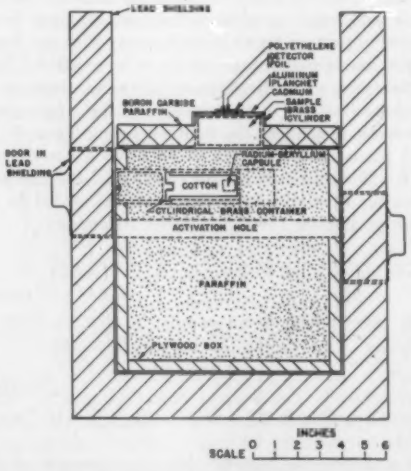


FIG. 7. Vertical sectional view through the center of a ½ Curie radium-beryllium source for using resonance detectors. A 4"-wall of lead and a 1/16"-sheet of cadmium in front of the source is used for protection against radiation.

Use of cadmium and other filters. For certain analyses, particularly those in which the sample contains elements that have resonance peaks near the thermal region, it may be advantageous to change the energy distribution of the beam with appropriate filters. Cadmium filters can, for example, be used to obtain the transmission for neutrons below 0.4 ev. Since cadmium has a strong absorption resonance at 0.180 ev, a thickness of about 0.6 mm removes practically all neutrons with energies below 0.4 ev. The

neutrons not transmitted by such cadmium filters are called c neutrons.

By making measurements with and without a cadmium filter, transmissions can be obtained for neutrons with energies above and below the cadmium cutoff. Four measurements are required:

1) Open beam intensity, I_o
2) Intensity with the sample in the beam, I_{sample}
3) Intensity with the cadmium filter in the beam, I_{Cd}
4) Intensity with both cadmium filter and the sample in the beam, $I_{Cd+\text{sample}}$

The transmission T_c for the c neutrons is

$$T_c = \frac{(I_{\text{sample}} - I_{Cd+\text{sample}})}{(I_o - I_{Cd})} \qquad (1)$$

and the transmission T_{ec} for the neutrons with energies above the cadmium cutoff—i.e., epi c neutrons—is given by

$$T_{ec} = \frac{I_{Cd+\text{sample}}}{I_{Cd}} \qquad (2)$$

These transmission values can then be used as will be described later for determining the composition of the sample.

Another filtering material that has been particularly useful in neutron measurements is boron, because the cross section is known to be directly proportional to $1/v$ or $+1/\sqrt{E}$. By means of boron filters of different thicknesses, the energy distribution of the neutron beam can be changed. The thicker the boron filter, the higher the average energy of the neutron beam. In this way, the cross section of a sample for different average energy distributions may be determined.

Thermal neutron beam. For application to certain simple systems it is not necessary to select a narrow energy band of neutrons. Instead the rather broad energy band of neutrons slowed down in paraffin can be used (Fig. 1). This distribution varies somewhat with the source of neutrons and with the temperature of the paraffin, but the observed transmissions are effectively those for neutrons of an energy of about 0.04 ev. Applications of this method to cases where one element in a mixture has a high cross section for thermal neutrons will be described later.

Cross Sections for Neutron Interactions

The magnitude of neutron interactions is usually expressed in terms of "cross sections." The unit is the barn (1×10^{-24} sq cm), which is of the order of physical area of nuclei. Cross sections for many reactions can be measured by transmission experiments as discussed in the following.

When an essentially unidirectional beam of neutrons is incident on a sample of material, some of the neutrons pass through unaffected, and the others are either absorbed or scattered from the beam as a result of neutron interactions. This attenuation of the neutron beam can be determined in a suitable experimental arrangement, shown diagrammatically in Fig. 8. The fractional decrease in intensity dI/I_x of a neutron beam in passing through a layer dx (Fig. 8) is equal to the ratio of the effective area of the nuclei in the layer to the total area of the layer. The effective

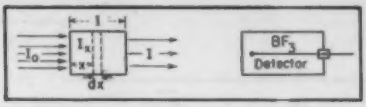


FIG. 8. Neutron cross sections from transmission measurements: I_o = initial neutron intensity; I_x = neutron intensity at x; l = thickness of sample.

area presented by the nuclei is given by the total effective cross section σ_t of each nucleus times the number of nuclei in the layer or $\sigma_t\, n\, A\, dx$, where n is the number of nuclei per cc and A is the area. Hence

$$dI/I_x = -\sigma_t\, n\, A\, dx/A = -\sigma_t\, n\, dx, \text{ from which}$$
$$I = I_o e^{-\sigma_t n l} \qquad (3)$$

where I_o is the initial intensity of the neutron beam, and I is the intensity after it has passed through the sample of thickness l. Hence, the total cross section per nucleus in cm² can be calculated from the results of transmission measurements by using Eq. (3) in the form

$$\sigma_t = \frac{1}{nl} \ln \frac{I_o}{I} = \frac{1}{nl} \ln \frac{1}{T}. \qquad (4)$$

Since the number of atoms per cc is given by $\rho N/M$, where M is the atomic weight, ρ is the density, and N is Avogadro's number,

$$\sigma_t = \frac{M}{\rho N l} \ln \frac{I_o}{I} = \frac{M}{\mu N} \ln \frac{I_o}{I}, \qquad (5)$$

in which μ is the grams per square centimeter of the element in the path of the neutron beam.

The cross section obtained in this way is the total cross section for all processes that tend to deflect the neutrons from their straight line of flight. Charged-particle scattering measurements and the lifetime energy relationship in heavy-charged-particle emitters indicate that the actual physical radius of an element of mass number A is given approximately by $1.5\times10^{-13}\times A^{1/3}$. For an element of mass number of about 125, the radius of the nucleus would be 7.5×10^{-13} cm, or a cross section of about 1.8×10^{-24} cm² (1.8 barns). Cross sections for neutrons may vary from this value up to over 115,000 barns for gadolinium at a neutron velocity corresponding to an energy of about 0.002 ev; that is, the cross section of this nucleus at certain energies is many thousands of times larger than its actual physical cross section. Since the observed cross sections depend so markedly upon the velocity of the neutrons, it becomes necessary to examine more closely the processes that contribute to the cross section.

Nature of Neutron Interactions

One of the generally adopted views of nuclear interactions is based upon Bohr's (17) idea of the compound nucleus, as illustrated in Fig. 9. On the basis of this picture, a neutron that comes close enough to a nucleus to interact with it actually unites with it to form a compound nucleus. This new nucleus, excited by both the kinetic energy of the neutron and by the

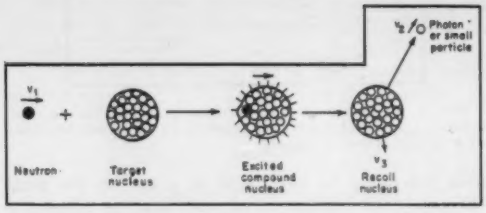


FIG. 9. Interaction of a neutron with a nucleus.

binding energy of the neutron with the nucleus (8–9 mev), may change to a more stable state in any one of a variety of ways. The relative probabilities for the different possible reactions are usually described in terms of "reaction widths," $\Gamma\chi$. The total cross section σ_t obtained from transmission measurements is the sum of the cross sections for all the absorption and scattering interactions summarized in Table 1. Thus the total cross section for transmission of crystals for slow neutrons will be given by

$$\sigma_{total} = \sigma_a + \sigma_{el} + \sigma_{inel} + \sigma_{coh} + \sigma_D + \sigma_m + \ldots., \quad (6)$$

in which the terms refer respectively to cross sections arising from absorption, elastic, inelastic, coherent Bragg scattering, diffuse or incoherent effects, and magnetic effects.

Absorption. Except for a few of the lighter elements, the most probable absorption reaction for slow neutrons is the (n, γ) reaction, in which the incident neutron is retained by the nucleus and a photon (γ) is emitted. This reaction is sometimes called radiative capture, because the γ-ray is emitted from the compound nucleus very shortly after it is formed (about 10^{-14} sec). The atomic number does not change in this process, but the mass number increases by one unit. If the isotope does not normally exist in nature, it will be radioactive. The properties of many of the radioactive isotopes formed in this way are suitable for chemical analysis by the radioactivation method.

Scattering. When a neutron rather than another particle is emitted from the compound nucleus, scattering results, and the process is called an (n, n) reaction. For most of these reactions neutrons are emitted nearly isotropically from the compound nuclei, and, consequently, very few of them reach the detector if good geometry is maintained. For good geometry the incident neutron beam should be essentially parallel, and the detector should be sufficiently distant from the sample that it subtends only a negligible solid angle.

Scattering may be inelastic if a part of the kinetic energy is lost by a fast neutron in exciting the nucleus to higher energy levels. Slow neutrons may also be involved in inelastic molecular collisions when a part of their kinetic energy is used up in breaking bonds or in exciting higher vibrational and rotational energy states of molecules or crystals.

Elastic-type collisions occur when the kinetic energy of the neutron and nucleus remains constant, and the interaction may be treated as a billiard-ball–type of collision. This is the main process by which fast neutrons are slowed down by the lighter elements.

When the energy or wavelength of the neutron is decreased to the thermal region where the associated wavelength is of the order of the distance between atoms in crystals, diffraction effects occur (*5*) in accordance with the Bragg relation, $n\lambda = 2d \sin\theta$. With a heterogeneous beam of neutrons Laue patterns may be obtained, whereas with a monoenergetic or monochromatic beam powder patterns can be taken with a neutron spectrometer. The intensity of the coherently scattered neutrons depends upon scattering from nuclei, but x-ray scattering involves the electrons of the atoms, and therefore depends markedly upon the atomic weight of the element. Neutron scattering, on the other hand, is about as intense for the nuclei of light atoms as for heavy atoms. For example, the relative coherent scattering cross sections in barns for a few elements are: H = 1.8, D = 5.4, O = 4.2, Na = 1.5, Cu = 7.3, Bi = 9.4. This makes possible the determination of the position of hydrogen in crystals by neutron diffraction where it would not be possible by x-ray diffraction. If the absorption cross section is large for one or more of the elements in a crystal, the intensity of the beam may be reduced so much that neutron diffraction will not be very useful.

Differences between neutron diffraction and x-ray diffraction also occur with respect to *diffuse scattering* effects that arise from such things as differences in the *scattering amplitude* and the *spin* of the isotopes of the element. Some elements, such as H^1, Li^6, Ti, and Mn, scatter neutrons with a *phase* opposite to that of D, Li^7, and most other elements (*5*). Consequently the amplitude of the scattered wave from planes in crystals containing nuclei of opposite scattering phase will be reduced. This effect is useful in certain structure problems, particularly those involving hydrogen, where both the hydrogen and deuterium compounds can be studied.

When the energy of the neutrons is reduced to a value such that the wavelength is equal to $2d$ for the first Bragg reflection, no coherent crystal scattering will occur. Neutrons of longer wavelength can then readily pass through the crystals. This effect has been used to obtain neutron beams of long wavelength by filtering through BeO (*18*). With such a filter, neutrons with wavelengths less than about 4.5 A are scattered from the beam. The residual cross section for the longer wavelengths is then caused by absorp-

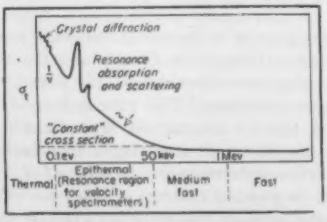


FIG. 10. General variation of cross sections with neutron energy.

tion, inelastic molecular effects, crystal imperfections, spin, isotope, temperature effects, etc. In addition, paramagnetic (*19*) and ferromagnetic substances have an additional effect caused by the interaction of the nuclear magnetic moment of the neutron and the electron magnetic moment of the unpaired electrons. Paramagnetic scattering becomes important only at the lower energies (long wavelengths).

Variations in Cross Sections with Neutron Energy

Marked variations exist in the cross sections for neutron interactions as the velocity of the neutron is changed. At high energies (1 mev), where the wavelength of the neutron is of the same order of magnitude as the radius of the nucleus ($\lambda \sim R$), the effective total cross section is roughly twice the geometric size of the nucleus or $2\pi r^2$ as measured by other methods—i.e., from 1 to 10×10^{-24}cm^2 (1–10 barns). In this high-energy region, the principal processes involve particle emissions, primarily scattering [(n, n) reactions]. However, there are some (n, p) and (n, α) reactions. As the energy of the neutrons is decreased, the cross section increases approximately as $1/v$, as illustrated in Fig. 10.

Resonance absorption and scattering of slow neutrons. Many of the elements, particularly those with atomic masses above 100, show regions of resonance absorption and scattering where a marked increase in cross section occurs at definite neutron energies (Fig. 10). One or more of these resonances exist for many nuclei. The fact that they occur at specific neutron energies may serve as an indication of the presence or absence of a particular nuclear species in an unknown sample. Furthermore, the large cross section at resonance is useful in quantitative determinations of a limited number of elements, some of which can be determined chemically only with difficulty. Examples will be given in a later section.

The shape of the resonance curve is given by the Breit-Wigner formula (*1*). The cross section at an energy E (electron volts) in the region of a resonance for an (n, γ) reaction is:

$$\sigma_{(n,\ \gamma)} = \frac{\lambda^2}{4\pi}\ g\ \frac{\Gamma_n \Gamma_\gamma}{(E-E_o)^2 + (\Gamma/2)^2} \qquad (7)$$

where λ is the wavelength [$\lambda = \hbar/(mv)$] of the incident neutron, and g is a statistical weight factor for the spins of the target nucleus, the compound nucleus, and the neutron. $\Gamma\gamma$ is the partial level width (proportional to the reaction probability) of the (n, γ) process. It is convenient to include the value of g in this neutron width. $\Gamma\gamma$ is the partial level width with respect to the (n, γ) process. $\Gamma = \Gamma n + \Gamma\gamma$ is the full width of the resonance peak at half its maximum value σ_o. E is the energy of the incident neutron, and E_o is the resonance energy.

For low-velocity neutrons, $\Gamma\gamma$ is nearly independent of velocity, whereas Γn is proportional to v. The maximum possible cross section for the (n, γ) process would be

$$\sigma_{o(n,\gamma)} = \frac{\lambda^2}{\pi} \cdot \frac{\Gamma_n \Gamma_\gamma}{\Gamma^2}, \qquad (8)$$

or $\lambda^2/4\pi$ at $E = E_o$ if $\Gamma n = \Gamma\gamma$. This would be a possible total cross section of $\lambda^2/2\pi$ for the sum of both $\sigma_{o(n,\gamma)}$ and $\sigma_{o(n,n)}$. A few nuclei such as Pd^{108}, Sm^{152}, and W^{186} appear to have levels in which $\Gamma\gamma \sim \Gamma n \sim 0.1$ ev.

Resonance capture. In most cases, however, $\Gamma n < \Gamma\gamma$ by a factor of 10 to 100, so that $\Gamma\gamma \cong \Gamma$ and the maximum possible cross section for resonance absorption is $\sigma_o = \lambda^2/\pi(\Gamma n/\Gamma\gamma)$. Since Γn varies as the velocity v or as $\sqrt{E}$, the cross section $\sigma_{(E)}$ for an energy E other other than the resonance energy can be obtained by bringing Eq. (7) into the following form:

$$\sigma_{(E)} = \left(\frac{E_o}{E}\right)^{1/2} \frac{\sigma_o \Gamma^2}{4(E-E_o)^2 + \Gamma^2} \qquad (9)$$

At energies low compared to E_o, Eq. (*9*) shows that $\sigma_{(E)}$ is proportional to $1/\sqrt{E}$ or to $1/v$. This is the well-known $1/v$ law. Examples of the above are Rh^{103}, In^{151}, and Au^{179}, in which $\Gamma\gamma$ is about 0.1 ev compared to 0.001 ev for Γn.

Resonance scattering. The cross section $\sigma_{(n,n)}$ for elastic scattering of low-energy neutrons in the region of a resonance is

$$\sigma_{(n,n)} = \frac{\lambda^2}{\pi} \times \frac{\Gamma_n^2}{4(E-E_o)^2 + \Gamma^2}, \qquad (10)$$

which, at the resonance energy E_o, gives a maximum cross section of λ^2/π. There are cases of levels, such as in Mn and Co, in which scattering is the more favored process, $\Gamma n \sim 10$ ev and $\Gamma\gamma \sim 0.1$ ev.

The 1/v region. At low energies, the cross section for scattering varies as $(\lambda^2/\pi) \times (\Gamma^2 n/4E_o^2)$, and

TABLE 3

Constants for the 1/v Region for a Number of Elements

(Equation: $= a + b/v = a + c/\sqrt{E}$)

Element	a Constant scattering cross section	c Slope
Ag	6.6	9.05
Al	1.48	0.036
Au	12.4	14.5
B	3.8	113.0
C	4.8	0.0007
Co	6.7	6.4
Cu	7.8	0.54
F	4.0	0.0016
Fe	11.1	0.34
Hf	84.6	38.7
In	14.0	64.5
Li	1.5	11.5
Mn	2.26	2.24
Nb	6.4	0.10
Nd	14.4	14.6
Ni	17.0	0.77
O	3.7	< 0.0001
Rh	6.0	23.6
Sn	4.3	0.088
Ta	7.2	3.2
W	5.7	2.72
Zr	6.8	0.016

since λ varies as $1/v$ and Γ_n varies as v, the scattering cross section should be fairly constant. Hence, the total cross section $[\sigma_{total} = \sigma_{capture\ (n,\gamma)} + \sigma_{scattering\ (n,n)}]$ in the $1/v$ region is made up of a constant scattering term plus a capture term that varies as $1/v$ or as $1/\sqrt{E}$. Thus, the cross section in this region can be expressed by an equation of the form $\sigma_{(E)} = a + b/v$ or $\sigma_{(E)} = a + c/\sqrt{E}$. The magnitudes of the absorption cross sections in this region, as well as the slopes of the $1/v$ curves, differ for a number of the elements (Table 3 and Fig. 11). Consequently, a method of analysis of certain simple systems can be based upon

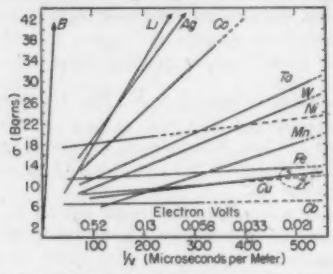


FIG. 11. Typical $1/v$ lines for several elements.

the transmission at two different neutron velocities. This method would give adequate precision only in cases where the $1/v$ slopes are markedly different for the elements in the sample.

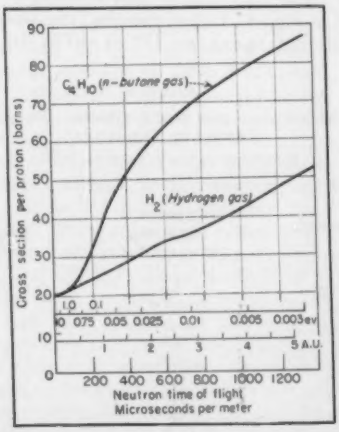


FIG. 12. Graph of neutron cross section n-butane and hydrogen as a function of neutron energy. (Approximate corrections have made for translational motion.)

Molecular effects. In the case of the lighter elements, such as hydrogen and deuterium, chemical binding effects become significant below energies of 1 ev. Actually the scattering is proportional to the square of the reduced mass of the neutron and the scatterer (*1*). If the hydrogen atom is free, the reduced mass $\mu \cong 0.5$. However, when hydrogen is bound in heavy molecules such as paraffin, the reduced mass will be $\mu \cong 1$. Consequently the ratio of the cross section of the free hydrogen atoms to a rigidly bound one is approximately $(1/0.5)^2 = 4$. Or, in general, the cross section σ_b for a rigidly bound nucleus of mass A relative to the cross section σ_f of the same nucleus in a free state will be given by $\sigma_b = \sigma_f[A+1)/A]^2$.

When the energy of the neutron is considerably higher than the vibrational energy of the C—H bond in paraffin (i.e., $E >> h\nu \sim 0.4$ ev), H may be separated from the molecule, and the cross section for hydrogen is what would be expected for free hydrogen atoms. At energies of the order of $h\nu$, however, the neutron can lose energy to the vibration of the hydrogen atom or other groups in the molecule. In this case the hydrogen atom is essentially bound, and the cross section increases to about four times that at the higher energies. Experiments show, in fact, that the cross section for hydrogen bound in a hydrocarbon molecule does increase from about 20 barns in the region of 10–1 ev to over 80 barns at energies of about 0.005 ev, as shown in Fig. 12 (*21*).

These results indicate that thermal neutrons (0.026 ev) would be quite suitable for analyzing certain materials for hydrogen-containing compounds. Specific applications of thermal neutrons to such analysis will be considered later. Also, it appears that such cross-section curves plotted as a function of energy may give some useful information on the absorption and combination of hydrogen with metals.

Analysis by Resonance Absorption and Scattering of Neutrons

Neutron absorption and scattering resonances are characteristic of a particular nucleus and therefore can be used to analyze for the presence of that nucleus. The cross section vs. energy curve for tantalum shown in Fig. 13 is typical of the experimental results obtained for many of the elements. As shown in this curve, tantalum has a large resonance absorption at 4.1 ev. This can be used not only to indicate the presence of tantalum but also to measure quantitatively the amount of tantalum in a sample that contains no elements with interfering resonances. It is, for example, useful in determining the percentage of tantalum in a sample of columbium. Similar curves have been obtained and compiled for many of the elements (*22*).

The principal resonances for a number of the elements are given in Table 4. Those elements with large cross sections can be detected qualitatively and determined quantitatively in the absence of elements with interfering resonances or high cross sections in the regions of the resonances; consequently it is necessary to have some knowledge of the nature of the samples. Resonances for the lighter elements (atomic weights below 100) occur only at relatively high energies, where the velocity selectors described previously are not very useful.

Examples of cases where analyses appear to be feasible are: Ta in Nb; Hf in Zr; In in Sn; Mn in Al or Fe; Co or Mn in steel; the rare earth elements; and

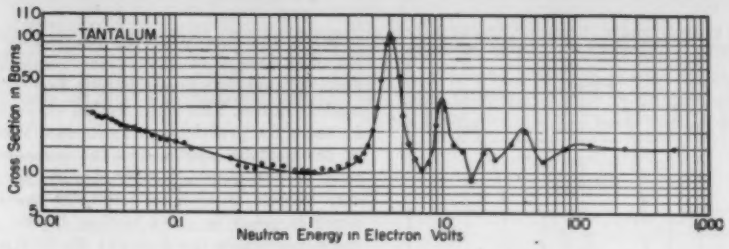


FIG. 13. Slow neutron cross-section curve of tantalum.

thicknesses of films or electroplates of Ag, Au, Rh, or Cd. The analysis can be done by obtaining an empirical working curve from a series of appropriate standards, just as is done in analysis by light absorption, or it can be done from a single curve, if the Breit-Wigner constants for the resonance curve of the element are known. This is illustrated in the following section by the case of hafnium impurity present in zirconium.

In Fig. 14 the transmission as a function of neutron energy is given for a sample containing 160. mg/cm²

TABLE 4

SLOW NEUTRON RESONANCES

Element	$E_o$ev	$\sigma\Gamma^2$ barns (ev)²
Antimony	5.8	12
	15.	35
	21.	35
Bromine	35.7	220
	54.	140
	104.	250
	136.	1000
Cadmium	0.176	828
Chromium	3950.	61.5×10^6
Cobalt	126.	2.3×10^5
	5500.	—
	8000.	—
Copper	3000.	—
Dysprosium	1.9	100
	5.	300
Europium	0.5	500
	3.	700
	10.	400
	25.	300
Gadolinium	0.04	90
Gallium	100.	846
	296.	4.92×10^4
Germanium	95.	800
Gold	4.87	638
Hafnium	1.07	38
	2.37	—
	5.5	—
	7.3	—
Indium	1.45	210
	3.8	12
	8.6	30
Iodine	20.6	4
	32.	135
	42.	135
Iridium	0.64	5 to 20
	1.27	5 to 20
	5.2	55
	8.7	50
	25.	—
Iron	950.	—
Manganese	335.	1.4×10^5
	2800.	—
	8400.	—
Mercury	−2.0	—
Osmium	6.5	10
	8.8	35
	20.	25
	28.	8
	42.	10
	84.	—

SLOW NEUTRON RESONANCES—(*Continued*)

Element	$E_o$ev	$\sigma\Gamma^2$ barns (ev)²
Platinum	11.5	55
	18.2	30
	100.	—
	1000.	—
Rhenium	2.2	46
	4.4	67 ($\sigma_o\Gamma$)
	5.9	24 ($\sigma_o\Gamma$)
	7.2	91 ($\sigma_o\Gamma$)
	11.3	30
	13.1	45 ($\sigma_o\Gamma$)
	16.7	46
	21.1	120 ($\sigma_o\Gamma$)
Rhodium	1.27	150
Ruthenium	9.8	11
	15.2	11
	24.1	16
	40.9	29
Samarium	0.10	50
	10.	200
Silver	5.1	300
	15.9	23
	29.6	—
	39.7	—
	51.	—
	66.	—
	84.	—
	93.	—
Sodium	3000.	—
Tantalum	6.1	—
	10.3	44
	13.6	9
	20.	9
	24.	35
	35.	97
	39.	197
Thallium	1300.	9×10^5
Tungsten	4.0	13
	7.4	5
	18.0	3000
	45.	400
	180.	1000
	1100.	
Zinc	520.	6.9×10^4
	1100.	2.3×10^4
	3800.	2.5×10^5

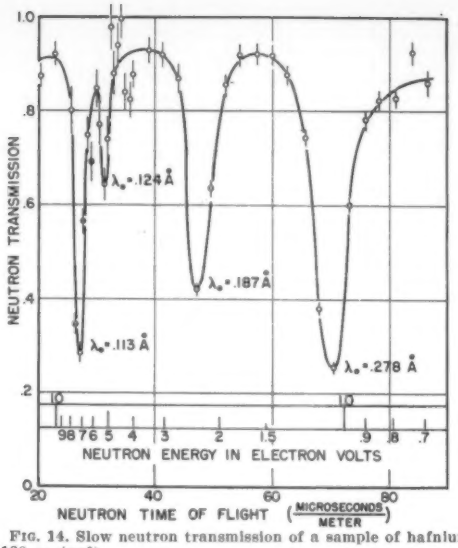


FIG. 14. Slow neutron transmission of a sample of hafnium (160 mg/cm²).

of hafnium. A section of a similar curve is given in Fig. 15 for a sample of zirconium, 16.3 g/cm². It is obvious from these curves that the resonances in the zirconium sample occur at about 47 and 70 μsec/m, or 2.37 and 1.07 ev, the same as resonances in the sample of hafnium. Resonance absorption at this energy is characteristic of the hafnium nucleus and can be used as a qualitative identification of this element. The following treatment will show how the area of this resonance dip can be used for quantitative estimation, once the appropriate constants are known for the element.

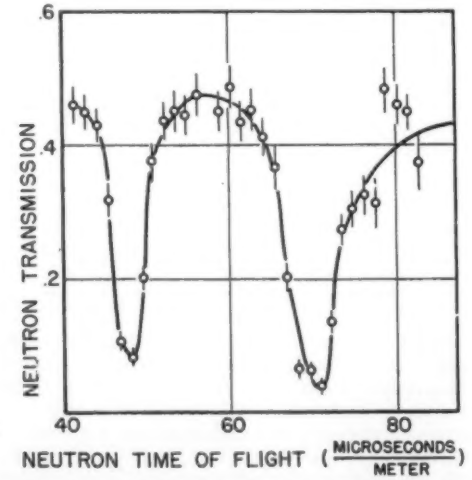


FIG. 15. Slow neutron transmission of 16.3 g/cm² of zirconium metal containing hafnium as an impurity

When the energy of the neutron is not near the resonant energy of any of the isotopes present, the cross section is approximately $4\pi r^2$ where r is the nuclear radius. This cross section varies between 2 and 11 barns for practically all elements. When the energy of the neutron approaches the resonant energy, the cross section increases very rapidly. In some cases, it may become as high as 1,000,000 barns at E_0. This rapid increase in cross section in the vicinity of a resonance causes the resonant dip in the transmission curve.

In the transmission curve for a sample of material, the observed transmission near a resonance can be divided into two parts: (*a*) the part which is due to the resonance absorption and scattering of a particular isotope and which changes rapidly with energy, and (*b*) the part which represents the sum of the elastic scattering cross sections of all nonresonant nuclei present and which does not vary rapidly with energy. Since one part of the cross section does, and the other part does not, vary rapidly with the energy, this "background" transmission (the part that does not vary rapidly with energy) can usually be obtained without difficulty.

It is obvious from the transmission curve of zirconium with the hafnium impurity that the hafnium transmission dip recovers to the background transmission of approximately 0.49. A derived "resonance transmission curve" for the hafnium in this sample of zirconium can be obtained by dividing the observed transmission curve by the background transmission. This derived transmission curve is the one used for the quantitative estimation of an element.

Effect of resolution width. To obtain the quantity of an element from its resonance transmission curve, one must consider the method by which the data are obtained.

In the modulated cyclotron velocity selector, as described above, there is approximately uniform production of neutrons for a time τ and detection of the neutrons for an interval of time τ'. Suppose for simplicity (and usually applied in practice) that we let $\tau = \tau'$. Then neutrons having times-of-flight between $t_1 - \tau$ and $t_1 + \tau$ will be detected and recorded. The probability that the particle having a time-of-flight t between $t_1 - \tau$ and $t_1 + \tau$ being detected will be proportional to the sum of area of the production pulse and the detection pulse overlapping at the time t. Therefore, the probability of a particle of time-of-flight t being detected will be zero at $t = t_1 - \tau$, increase linearly until $t = t_1$, and then decrease linearly to zero at $t = t_1 + \tau$.

The probability of detection can be represented mathematically by a distribution function expressed by the following relations:

$$\Phi(t,\tau) = 0 \text{ for } t < (t_1 - \tau)$$

$$\Phi(t,\tau) = \frac{1}{\tau^2}\,[t - (t_1 - \tau)] \text{ for } (t_1 - \tau) < t < t_1$$

$$\Phi(t,\tau) = \frac{1}{\tau^2}\,[(t_1 + \tau) - t] \text{ for } t_1 < t < (t_1 + \tau)$$

$$\Phi(t,\tau) = 0 \text{ for } t > (t_1 + \tau)$$

This distribution function is usually called the resolution function or resolution width of the apparatus. The relation of the resolution function of the apparatus to "cyclotron on time" and "detector on time" is given in Fig. 16.

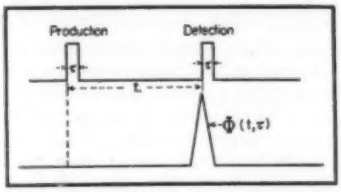


FIG. 16. Resolution function of the apparatus $\phi(u)$ showing relation to "cyclotron on time" and "detector on time."

If the constants for the Breit-Wigner formula are known, a calculated value for the transmission, T_c, of the sample for neutrons of energy E can be obtained from the equation

$$T_c = e^{-n'\sigma(E)}$$

Here n' is the number of atoms per cm² of the absorbing material and $\sigma(E)$ is the cross section of the material at the energy E as given by the Breit-Wigner formula. This, however, is not the curve that is observed experimentally, because the apparatus does not have infinitely sharp resolution. To match the experimental curve, it is necessary to include the effect of the resolution width of the apparatus.

The actual observed transmission curve is given by

$$T = \int_{-a}^{+a} \phi(u)\, T_c(E+u)\, du,$$

where $\phi(u)$ is the smearing function representing the resolution width of the aparatus on the energy basis and the a is the half-width of the resolution function.

The observed transmission at a particular energy in the vicinity of a resonance can be quite different from the calculated transmission of the sample at this point. Therefore, the observed transmission value at the minimum of the transmission dip is not a reliable measure of the amount of the resonance absorber. This problem is similar to that encountered in optical spectroscopy, where the resolution width of the spectrometer is much wider than the absorption band.

Area of the resonance dip. The difficulty noted can be circumvented by considering the integrated effect of the level over the energy range where it is effective. Let us define a quantity A which is given by the expression

$$A = \int_{E_1}^{E_2} (1-T)\, dE$$

where E_1 is less than E_o and E_2 is greater than E_o. Quantity A represents the area between the observed resonance transmission curve and unity transmission and is proportional to what we shall call the "strength of the resonance level." The quantity A cannot be determined analytically for all cases encountered experimentally, but must be determined by numerical integration. However, when the energy of the resonance, E_o, is much greater than the width of the level, Γ, A can be evaluated exactly for the case of a very thick sample ($n\sigma_o >> 1$) and for the case of a thin sample ($n\sigma_o << 1$). These results are

$$A_{\text{thick}} = \sqrt{\pi n' \sigma_o \Gamma^2} \text{ or } n' = \frac{A^2_{\text{thick}}}{\pi \sigma_o \Gamma^2}$$

and

$$A_{\text{thin}} = \frac{\pi}{2} n' \sigma_o \Gamma \text{ or } n' = \frac{2A_{\text{thin}}}{\pi \sigma_o \Gamma}$$

A more complete treatment of this method is given in an article by Havens and Taylor (*2*), in which corrections to the thick and thin sample approximation have been calculated for all values of $n\sigma_o$. The procedure for obtaining more detail about the samples by fitting calculated curves to experimental data by numerical integration has been given by Havens and Rainwater (*23*).

Example of the Resonance Absorption Method

Application of the resonance absorption method to the specific case of the hafnium impurity in zirconium will illustrate the procedure for a typical analysis. In the transmission dip for the 16.3 g/cm² or zirconium shown in Fig. 15, the constant part of the observed transmission is $T = 0.496$. The observed transmission at each point is divided by 0.496, and the corrected transmission curve is then replotted. For the level at 70 μsec/m (1.07 ev) the area between this corrected transmission curve and unity transmission is evaluated by numerical integration and found to be $A_t = 10.4$ μsec/m.

Since the minimum in the corrected transmission curve is close to zero, the thick sample approximation is used. Substituting the known value of $\sigma_o\Gamma^2 = 38$ for this level of hafnium, and the experimental value of the area A_t into the thick sample formula, gives $n' = 8.4 \times 10^{20}$. The value of σ_o for this level is 3,800b, so that $n'\sigma_o = 3.2$, which shows that the thick sample approximation is not very good. The correction factor (*2*) for a value of $n'\sigma_o = 3.2$ is about 19%, which means that $n' = 9.8 \times 10^{20}$, or 0.29 g/cm² hafnium. This corresponds to a 1.7% impurity of hafnium in the zirconium, with an estimated error of ±10% in the hafnium content. This is in reasonable agreement with the spectrographic analysis of 1.9% Hf. When a more precise numerical analysis of these data is made, the results can be obtained with higher accuracy. Also, direct comparison with standards of known hafnium content can be used to improve the accuracy of the determinations. A more complete analysis of this and other cases will be published in the near future.

To be determinable in small amounts by the method noted, the Breit-Wigner constants σ_o and Γ should be known, and the amounts of the element in the neutron beam should be such that $n'\sigma_o$ is not smaller than about 0.2. Otherwise, the transmission at the resonance is too great for good measurements. For hafnium, using the 1.07-ev level, this means a foil containing 15.7 mg/cm² can be determined to about ±10%. For indium, a foil

containing about 1.5 mg/cm² (0.002 mm thick) can be determined to within about ±10%, and calculations for gold with $\sigma_o\Gamma^2 = 612$, $\sigma_o = 24{,}000$ barns, and $\Gamma = 0.16$ show that 2.74 mg/cm², or a thickness of 0.0014 mm, is determinable.

Detectability of a Resonance

Actually, the minimum quantity that can be determined depends upon the energy at which the resonance occurs and the constants of the nuclear resonance, as shown by the following considerations.

Because the data taken with the neutron spectrometer are usually on the time-of-flight basis, the expression given previously for the area of the resonance dip on the energy basis should be converted to the area on a time-of-flight basis. Since $dE/E = 2dt/t$, it can be shown (*2*) that

$$\sqrt{n'\sigma_o\Gamma^2} = \frac{2}{\sqrt{\pi}}\frac{E_o}{t_o} A_t,$$

where A_t represents the area on time-of-flight basis.

Experimentally the criterion for a resonance level is not the area under the resonance dip but the change in transmission at exact resonance. It is difficult to give exact criteria for the strength and energy of the level for a specified transmission, because the actual observed minimum transmission depends on the resolution width of the apparatus and the actual nuclear constants of the level. However, we can examine the conditions at the two limiting cases of the resolution width of the apparatus: (1) when the level is completely resolved, and (2) when the resolution width is much wider than the resonance. For these cases the minimum observable number of atoms/cm² can be estimated.

In the case of Cd, the level has been completely resolved with $E_o = 0.180$ ev, $\Gamma = 0.115$ ev, and $\sigma_o = 7{,}200$ barns. The minimum transmission will be at the resonance energy E_o when $T = e^{-n'\sigma_o}$. The maximum ratio of the constant transmission to the resonant transmission that can be observed is about 0.9, or $n'\sigma_o \cong 0.1$, which gives $n' = 1.39 \times 10^{19}$ or 2.6 mg/cm².

For Mn, where $E_o = 335$ ev and $\Gamma \cong 13$ ev, with $\sigma_o\Gamma^2 = 1.4 \times 10^6$, the difference in time-of-flight between the resonant neutron and a neutron of energy $E_o \pm \Gamma$ corresponds to about 0.08 μsec/m. Since the best resolution width so far obtainable is about 0.9 μsec/m, the observed width of the resonant dip on the time-of-flight basis will be almost completely due to the resolution width of the apparatus. In the case of Mn, if the production interval τ equals the detection interval, the observed transmission dip will be triangular in shape and have a base equal to twice the interval τ. Using the maximum ratio of the constant transmission to the resonant transmission as 0.9,

$$n' = 1.3 \times 10^{18}, \text{ or } 1.4 \text{ mg/cm}^2.$$

For Mn, $\sigma_o \cong 7{,}800$ barns; therefore $n'\sigma_o = 0.1$, which means the thin sample approximation is the proper approximation to use.

It should be emphasized that even though the strength of the Mn level is more than 2,000 times the strength of the Cd level, the same number of atoms of Mn as of Cd must be present to obtain an observable effect. In the higher energy region, it is necessary to use a relatively thicker sample for determination of a resonance dip.

Analysis by Simple Transmission Measurements

In certain simple systems where the nature of the sample is known, it is possible to make an analysis by single transmission experiments. To reduce interferences, it may be advantageous to measure the transmission at a particular velocity, using a spectrometer or a resonance detector. In other cases, the transmission of an energy band of neutrons or of a beam of thermal neutrons may give the information desired.

To make an analysis by one of the above transmission measurements, the intensity of the beam is measured, first, without the sample in the beam (I_o) and then with the sample in the beam (I). This gives the transmission $T = I/I_o$. As shown above, the number of atoms in the beam is related to the transmission by the equation

$$-\ln T = \Sigma_i n'_i \sigma_i,$$

where n'_i is the number of atoms of ith kind per cm² and σ_i is the cross section of the ith atom in cm².

If the cross section and the amount of one element are such that they cause practically all the decrease in the intensity of the neutron beam, then the effect of the other elements can be neglected, and the number of atoms of the elements per cm² is given by

$$n' = -\frac{\ln T}{\sigma}$$

or

$$\mu = \frac{(-\ln T)M}{N\sigma},$$

where μ is the grams/cm² of the element, M is its atomic weight, and N is Avogadro's number. The percentage of the element is then given by

$$\% \text{ of element} = \mu/G \times 100,$$

where G is the total grams/cm² of the element and the matrix in which it occurs.

Binary mixtures in which one element has a greater cross section than the other can be analyzed if the cross sections of the two elements are known. In this case, it is necessary to know both the thickness and the density of the sample to give the total grams of material per cm². For such a mixture

$$-\ln T = (n'_A\sigma_A + n'_B\sigma_B) = \frac{\mu_A N}{M_A}\sigma_A + \frac{\mu_B N}{M_B}\sigma_B.$$

μ_A and μ_B are the grams/cm² of substances A and B; M_A and M_B are their respective atomic or molecular weights. Since the total grams/cm² of the sample is $G = \mu_A + \mu_B$, then $\mu_B = G - \mu_A$. Substitution in the equation above gives

$$-\ln T = \mu_A \frac{N}{M_A}\sigma_A + (G - \mu_A)\frac{N}{M_B}\sigma_B,$$

$$= \mu_A K_A (G - \mu_A) K_B,$$

where $K_A = N\sigma_A/M_A$ and $K_B = N\sigma_B/M_B$. Since T, G,

and the constants K_A and K_B are known, μ_A may be calculated. Then

$$\% \text{ of } A = \frac{\mu_A}{G} \times 100$$

Instead of direct calculations using the known cross section of the elements, it may be advantageous in many cases to prepare standards containing known concentrations of the element in a matrix similar to that of the unknown. Then, from a plot of $-\ln T$ vs. μ, the value of μ for the unknown can be read. Alternatively, if the sample is the appropriate type, the addition technique can be used. When the transmission of the unknown sample has been obtained, the measurement can be repeated after adding more known amounts of the element being determined. Using the linear relationship of $-\ln T$ vs. μ, one can calculate the amount of the element initially present.

Examples of cases in which analysis by simple transmission measurement may be applicable are cadmium in alloys with lead, bismuth, and tin; thickness of electroplated films of such elements as gold, silver, rhodium, cadmium, manganese, etc., on a base material of low cross section; hafnium in zirconium, indium in tin, tantalum in columbium; certain rare earths; hydrogen combined with, or dissolved in, metals; hydrogen in organic compounds; water in nonhydrogen-containing materials; etc. An interesting application of the above methods was the determination of hydrogen in fluorocarbons (*24*). It was possible to show, for example, that a sample submitted for analysis had 9.9 fluorine atoms/1,000 replaced by hydrogen.

In general, any element that has a high cross section can be determined if it is in a matrix or on a base material that has a relatively lower cross section. A partial list of elements with high cross sections in the thermal region is given in Table 5. The values are total cross sections (absorption plus scattering) for a neutron energy of 0.025 ev. They have been estimated from data reported in the literature, primarily from compilations such as the ones by Way *et al.* (*25*).

TABLE 5
TOTAL CROSS SECTIONS FOR THERMAL (.025 EV) NEUTRONS

Element	Cross section (barns)	Element	Cross section (barns)	Element	Cross section (barns)	Element	Cross section (barns)
A	1.4	Ga	19	Ni	22	Tl	13
Ag	66	Gd	42,000	O	4.2	Tm	114
Al	1.6	Ge	6.0	Os	29	V	12
As	9	H	(60–30)	P	4.5	W	23
Au	104	He	1.5	Pb	8.5	Xe	37
B	718	Hf	175	Pd	11.2	Y	4
Ba	9.3	Hg	400	Pr	16	Yb	50
Be	6.9	Ho	52	Pt	16.6	Zn	4.5
Bi	9.1	I	10.3	Rb	12.6	Zr	8
Br	11.5	In	194	Re	98		
C	4.8	Ir	450	Rh	155		
Ca	4.4	K	8.2	Ru	9		
Cd	2470	Kr	24	S	1.6		
Ce	6	La	18	Sb	8.3		
Cl	55	Li	70	Se	22		
Co	41	Lu	115	Se	21		
Cr	7.3	Mg	3.0	Si	2.2		
Cs	50	Mn	15.3	Sm	8900		
Cu	11	Mo	9.6	Sn	4.6		
Dy	1150	N	12.7	Sr	11		
Er	200	Na	4.5	Ta	25		
Eu	4800	Nb	6.4	Th	55		
F	4	Nd	72	Te	10		
Fe	13.5	Ne	2.8	Ti	20		

Absorption of Thermal Neutrons

If an element that absorbs neutrons is placed in a region where there is a flux of neutrons, the reduction in the flux is a measure of the quantity of the neutron-absorbing elements. An example of the procedure for use with a radium-beryllium source is the determination of boron in a sample of boron carbide (*26*). The sample is ground until the particle size is below 325 mesh. This material is suspended in vigorously stirred water that surrounds a neutron detector. The assembly is placed in a block of paraffin in which the neutron source is embedded. After measuring the neutron intensity with the detector, the sample is removed, and the quantity of boron required to reduce the flux to the same value is determined by addition of a boron compound of known purity. By this method it was possible to determine that a 3- to 4-g sample of boron carbide contained 59.5% boron. Similar absorption methods can be used in the chain-reacting pile.

The pile reactivity method also depends upon the absorption of neutrons by the element to be determined. It is based on the fact that the introduction of a neutron-absorbing substance in a pile decreases the reactivity of the pile (*27*). To keep the power level constant, the control rods must be withdrawn a certain distance. By proper calibration with standards, a determination can be made of the weight of absorber in the sample, provided unknown interfering substances are not present.

The *pile oscillator* may also be applied to analysis in special situations (*28*), although its primary use is to measure absorption cross sections. Here, a sample containing a substance of high absorption cross section is passed back and forth close to a neutron counter suitably placed in the graphite of the pile.

The oscillation of the sample produces uniform fluctuations in the ion current of the detector in response to local depressions in the neutron flux as the sample passes the detector. Alternatively, the sample is passed in and out of the pile to produce a fluctuation in the power of the pile. Suitable amplifier and integrator circuits measure the magnitude of the effect.

A comparison of the effect for the sample with the appropriate standards would enable the estimation of the percentage of the absorber in the sample.

Neutron Activation

The radioactivation of foils of suitable elements is frequently used to measure neutron flux, as explained

in the previous discussion. Radioactivation is also a powerful tool for the determination of certain elements. It is particularly valuable for the determination of elements in very small concentrations. Inasmuch as this method has been recently reviewed (*3*), only a brief discussion will be given here.

The sample to be analyzed is placed in a flux f of neutrons for a time sufficient to produce a measurable activity as a result of absorption of neutrons by the element sought. The rate of growth of radioactive atoms N^* is given by the difference between the rate of formation of active atoms and their rate of decay:

$$dN^*/dt = f\sigma_{ac}N - \lambda N^*.$$

Integration for the time of irradiation gives the equation

$$N^* = \frac{f\sigma_{ac}N}{\lambda}(1 - e^{-\lambda t_1}),$$

from which the activity is

$$A_{t_1} = N^*\lambda = f\sigma_{ac}N(1 - e^{-\lambda t_1}) = f\sigma_{ac}N(1 - e^{-0.693 t_1/T_{1/2}}),$$

where f is neutron flux in neutrons/sq cm/sec; σ_{ac} is the cross section for the absorption of neutrons in sq cm/atom for the natural element; N is the number of target atoms; and λ is the decay constant for the radioactive isotope, which may be expressed in terms of its half-life $T_{1/2}$ by $\lambda = 0.693\ T_{1/2}$. A_t is the activity in disintegrations per second at the time t_1, when the neutron irradiation is stopped. These equations show that irradiation for a period of time equal to several half-lives gives practically the maximum activity obtainable ($f\sigma_{ac}N$), and that irradiation for a period of time equal to a half-life gives one half the maximum value.

If the activity is measured at a time t_2 after the irradiation was stopped, the disintegrations per second A_{t_2} will be given by:

$$A_{t_2} = A_{t_1}e^{-\lambda t_2}$$

or, combining with the above equations,

$$A_{t_2} = f\sigma_{ac}N(1 - e^{-0.693 t_1/T_{1/2}}) \times (e^{-0.693 t_2/T_{1/2}})$$

The number of atoms N of an element in a sample of weight g is

$$N = 6.02 \times 10^{23} \times g/M,$$

where M is the atomic weight. Substituting for N and then solving for g, the weight of the element in the sample is:

$$g = \frac{A_{t_2}M(e^{-0.693 t_2/T_{1/2}})}{6.02 \times 10^{23} f\sigma_{ac}(1 - e^{-0.693 t_1/T_{1/2}})}.$$

To calculate the weight of the element in the sample, it is necessary to know the neutron flux, the cross section for activation, and the half-life. In addition, the number of disintegrations per second must be determined rather precisely. This is not easy to do, because the actual count observed with the Geiger-Muller counter, for example, must be corrected for counter efficiency for the radiations; geometry (fraction of the solid angle effective in the counting); absorption of radiations by the walls, air, and the sample itself; forward scattering from the sample or surroundings; and backscattering from the sample mount, etc. All these factors tend to affect the net counting yield, which, for most cases, falls between 5 and 35%.

As a result, it is difficult to determine precisely the weight of the element from counting on a single unknown sample. Orders of magnitude or limiting concentrations are, however, frequently of interest. For example, a measured count of 2,200/minute for manganese ($\sigma_{ac} = 12$) taken directly after a saturation irradiation in a flux of 10^9 neutrons per second would, assuming a counting yield of 25%, indicate the presence of approximately 1 μg of Mn in the sample.

More precise determinations can be made by comparing the unknown sample with standards of similar composition. The unknown and standard are irradiated, and then counted, under as nearly identical conditions as possible. The weight of the element χ in the unknown is then given by:

$$\frac{\text{weight of } \chi \text{ in unknown}}{\text{weight of } \chi \text{ in standard}} = \frac{\text{activity from } \chi \text{ in unknown}}{\text{activity from } \chi \text{ in standard}}.$$

If chemical operations are necessary to remove bulk constituents or interfering radioactive elements, then both standard and unknown are treated in the same way. The element of interest is finally isolated, and its activity is determined and compared with the standard. To be certain of the radiochemical purity of the isolated element, it is advisable to determine its half-life and its aluminum or lead absorption curve. The resolution of the decay curve and the characterization of the radiations may also give valuable qualitative information about the presence of other elements. In fact, it may be desirable to run such a preliminary qualitative analysis on a sample before making the chemical separations.

When the element to be determined is present in trace amounts, a small known amount of the naturally occurring element is added after irradiation. This serves as a "carrier" to aid in the separation and isolation of the element. It also serves as a means of determining the "chemical yield" of the processes. The observed counting rates for the standard and unknown samples can then be corrected for chemical losses. In addition, corrections for self-absorption may be needed if the weights of the compounds counted are appreciably different for standard and unknown.

The principal source of uncertainty in such determination by the comparison method is the uncertainty in the counting rate. It is estimated that trace constituents can be determined with an accuracy of ±10%, which, for trace and impurity analysis, is frequently sufficient.

The sensitivity of the method is illustrated by the following. If an element such as manganese with an absorption cross section of about 10 barns is placed in a neutron flux of about 10^{12} neutrons/cm^2, about 10^{-10} g will produce a counting rate of about 100 counts per minute, assuming a 25% counting yield. This phenomenal sensitivity is only obtained with very high neutron fluxes because, with a 1-g radium-

beryllium source where the usable flux for activation is about 10^5 neutrons/cm^2/sec, it would take about 1 mg of manganese to give the same counting rate. Consequently, for low neutron fluxes, the method is not too sensitive. These low intensity sources, however, may find special applications in alloy or ore analysis where high sensitivity is not required. With a chain-reacting pile where high neutron fluxes are available, 50–75 of the stable elements have properties that are more or less suitable for determination by the activation method.

For practical application the element should have a sufficiently high activation cross section (*2, 25*), and the radioisotope produced should have a half-life not less than 30 seconds for longer than a few days. In cases where the neutron properties of the individual isotopes of the elements are known and have suitable properties, the isotopic ratio in samples can be determined in a similar way by the activation method.

The activation method is not limited to the use of neutrons. Charged particles from cyclotrons and electrostatic generators have also been used successfully (*29*).

References

1. Bethe, H. A., and Backer, R. F. *Rev. Modern Phys.*, **3**, 83 (1936); *ibid.*, **9**, 69 (1937); Livingston, M. S., and Bethe, H. A. *Ibid.*, 245; Rainwater, L. J. *Trans. N. Y. Acad. Sci.*, II (II), 68 (1949).
2. Taylor, T. I., and Havens, Jr., W. W. *Nucleonics*, **5**, (6), 4 (1949); Havens, Jr., W. W., and Taylor, T. I. *Ibid.*, **6**, (2), **66** (1950); *ibid.*, (4), 54 (1950).
3. Boyd, G. E. *Anal. Chemi.*, **21**, 335 (1949).
4. Paneth, F. A. *Radioelements as Indicators.* New York: McGraw-Hill (1928); Henriques, F. C., and Margnetti, C. *Ind. Eng. Chem. Anal. Ed.*, **18**, 476 (1946).
5. Wollan, E. O., and Shull, C. G. *Science*, **108**, 69 (1948); *ibid., Nucleonics*, **3**, (1), 8; (2), 17 (1948); Hughes, D. J. *Ibid.*, **6**, (2), 5; (3), 38; (6), 50 (1950).
6. Rainwater, L., *et al., Phys. Rev.*, **71**, 65 (1947); Hanson, A. O., Taschek, R. F., and Williams, J. H. *Rev. Mod. Phys.*, **21**, 635 (1949); Tyren, H. *Svedberg Memorial Volume*, Uppsala: Almquist & Wiksells, 224 (1945); Seidl, F. G., and Harris, S. P. *Rev. Sci. Instruments*, **18**, 897 (1947); McCallum, K. J. *Nucleonics*, **5**, (1), 11 (1949); Russel, B., *et al., Phys. Rev.*, **73**, 545 (1948).
7. Dunning, J. R., *et al., Phys. Rev.*, **48**, 704 (1935).
8. Fermi, E., Marshall, J., and Marshall, L. *Ibid.*, **72**, 193 (1947).
9. Selove, W. A. *Ibid.*, **76**, 187 (1949).
10. Johnson, G. W., Palevsky, H., and Hughes, D. J. *Ibid.*, **82**, 345 (1951).
11. Zinn, W. H. *Ibid.*, **70**, 102 A (1946); **71**, 752 (1947); Borst, L. B., *et al. Ibid.*, **70**, 108 A, 557 (1946).
12. Rainwater, L. J., and Havens, Jr., W. W. *Ibid.*, 136.
13. Rainwater, L. J., *et al. Ibid.*, **71**, 65 (1947).
14. Goldsmith, H. H., and Rasetti, F. *Ibid.*, **50**, 328 (1936); Tittle, C. W. *Nucleonics*, **8**, (6), 5; **9**, (1), 60 (1951).
15. Marshall, J. AEC Declassified Document MDDC-78.
16. Hanstein, H. B. *Phys. Rev.*, **59**, 489 (1941).
17. Bohr, N. *Nature*, **137**, 344, 352 (1936).
18. Fermi, E., and Marshall, L. *Phys. Rev.*, **72**, 408 (1947).
19. Ruderman, I. W., *et al. Ibid.*, **75**, 895 (1949); Ruderman, I. W., *Ibid.*, **76**, 1572 (1949); Halpen, O., and Johnson, M. H. *Ibid.*, **51**, 992 (1937); **52**, 52 (1937).
20. Goldhaber, M. *Slow Neutron Reactions.* Brookhaven Chemistry Conference No. 3 (July 1949); Abst., Washington meeting, Am. Phys. Soc. (April 1949); Yalow, A. A. and Goldhaber, M. *Phys. Rev.*, **68**, 99 (1945).
21. Melkonian, E. *Ibid.*, **76**, 1744, 1750 (1949).
22. Adair, R. K. *Rev. Mod. Phys.*, **22**, 249 (1950).
23. Havens, Jr., W. W., and Rainwater, L. J. *Phys. Rev.*, **70**, 154 (1946).
24. Burger, L. L., and Rainwater, L. J. AEC Declassified Document, AECD-2138 (1948).
25. Way, K., *et al. Nuclear Data.* Cir. Natl. Bur. Stand. No. 499 (1950).
26. Walker, R. AEC Declassified Document, MDDC-362 (1946).
27. Anderson, H. L., *et al. Phys. Rev.*, **72**, 16 (1947).
28. Hoover, J., *et al. Ibid.*, **74**, 864 (1948).
29. Seaborg, G. T., and Livingood, J. J. *J. Am. Chem. Soc.*, **60**, 1784 (1938); King, D. T. P., and Henderson, W. J. *Phys. Rev.*, **56**, 1169 (1939); Sagane, R., Equchi, M., and Shigeta, J. *Proc. Phys. Math. Soc.* (*Japan*), **16**, 383 (1942); *Chem. Abs.*, **41**, 7303 i (1947); Ardenne, M., and Bernhard, F. *Z. physik.*, **122**, 740 (1944).

The **Wayne University** biennial "Frontiers in Chemistry" lecture series began on Sept. 24 with a lecture by John G. Ferris, of the U. S. Geological Survey. Ng. Ph. Buu-Hof, of the Institut du Radium, Paris, spoke on Oct. 1, and on succeeding Monday evenings the following speakers will be presented: Harvey Diehl, C. S. Marvel, Robert S. Mulliken, G. B. B. M. Sutherland, and H. J. Emeléus (Cambridge University). Additional information may be obtained through George H. Coleman, Kresge-Hooker Scientific Library. Dr. Coleman is currently serving as head of the Chemistry Department during the tenure of J. Russell Bright as associate director of the newly organized Division of Contract Services at Wayne. John R. Richards, executive assistant to the president, has been serving as director.

James E. Lofstrom has been appointed special professor of radiology and chairman of the division in the Wayne University College of Medicine. The appointment was made jointly with Receiving Hospital, where Dr. Lofstrom has been named head radiologist. Funds for the university's contribution to his salary are available through a special grant from the National Fund for Medical Education. Dr. Lofstrom has been a member of the Wayne faculty since 1935.

Joseph M. Looney, chief of laboratories at the regional office of the Veterans Administration, Boston, has been appointed research professor of biochemistry at the Boston University School of Medicine. He is also consultant in endocrinology at St. Elizabeth's Hospital.

Frederick Morgan has been appointed controller of atomic energy in Britain. General Morgan succeeds Viscount Portal of Hungerford, chief of the British air staff during the war, who resigned.

A Microfluorometric Scanner for the Differential Detection of Cells: Application to Exfoliative Cytology

Robert C. Mellors[1] and Reuben Silver[2]

Sloan-Kettering Institute for Cancer Research and
Department of Pathology, Memorial Center, New York

THE PURPOSE OF THIS PAPER is to describe developmental work on a microfluorometric scanner designed for the automatic searching and detection of cancer cells in preparations (smears) of exfoliated cells, obtained from tissue secretions and spread on microscope slides.

The cytological and the cytochemical principles, which have been presented in preliminary form elsewhere (*1–3*), and which will soon be described in detail (*4*), involve staining the cells with a basic fluorescent dyestuff or *fluorochrome* under conditions that favor selective and stoichiometric combination of the dye with chemical constituents that are located principally in the nucleus of the cell. Each stained cell when illuminated with long-wave ultraviolet radiation acts as a self-luminous body, whose light emission can be measured with a microphotometer. The *primary* or the intrinsic fluorescence that is due to the natural cellular constituents is negligible in comparison with the *secondary* fluorescence induced by the dye-binding.

Cancer cells, in comparison with normal cells derived from the secretions of certain anatomical sites, such as the cervix uteri, combine with more fluorochrome and emit on the average per unit area two to three times the fluorescent light of normal cells. This conclusion is derived from a microfluorometric analysis and a statistical treatment of samples of the order of 100–300 cells in the vaginal smear and in the pleural fluid. Data for the cells of other anatomical sites, such as the urinary, the respiratory, and the gastrointestinal tracts, have not yet been obtained.

There exists, therefore, a quantitative means of differentiating normal and cancer cells which exfoliate

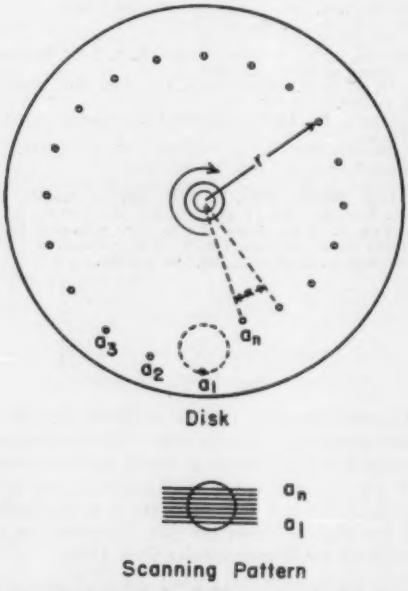


FIG. 1. Nipkow scanning disk. A spiral of apertures, a_n, spaced at an equal angular interval, $\alpha = 360°/n$, to produce n lines in the scanning pattern.

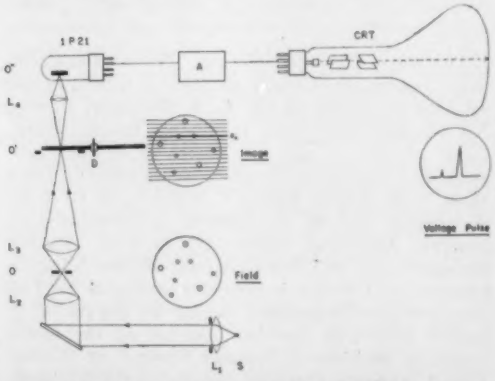


FIG. 2. Microfluorometric scanning of cells with oscilloscope presentation. *S*, source of Köhler illumination; L_1, field lens; L_2, condenser; *O*, object; L_3, objective; *O'*, image; *D*, scanning disk; L_4, auxilliary lens; 1P21, photomultiplier; *A*, amplifier; and *CRT*, cathode-ray tube, with voltage pulse from cells scanned along line, a_n.

[1] This work was done under a Damon Runyon Senior Clinical Research Fellowship of the American Cancer Society, Inc., and was supported in part by a research grant from the National Cancer Institute of the National Institutes of Health, USPHS.

[2] The authors wish to acknowledge their indebtedness for many helpful and enlightening suggestions to M. G. Brown and M. L. Polanyi, of the American Optical Company; W. C. Peacock, H. Beyer, and M. Berman, of the Sloan-Kettering Institute; and to thank Tracerlab, Inc., and the Sylvania Electric Company for the use of equipment.

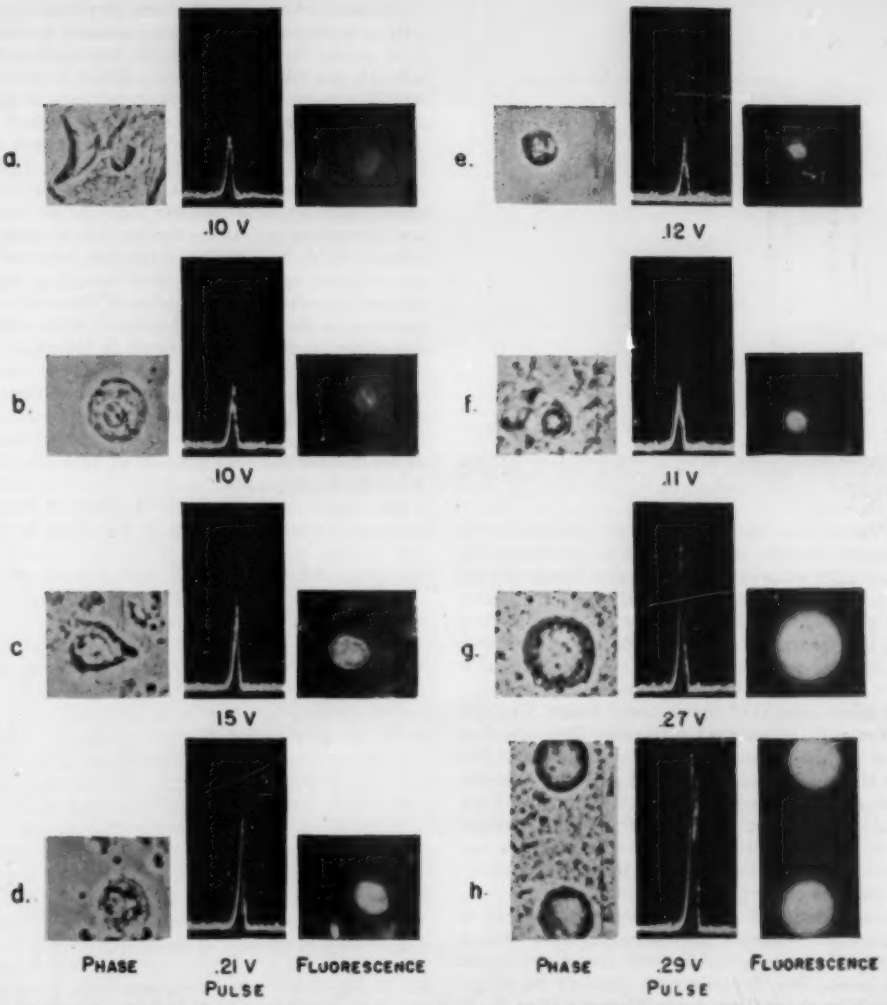


FIG. 3. Microfluorometric scanning. Fluorescence photomicrographs, oscilloscope tracings of voltage pulse and phase photomicrographs of cells. Vaginal smear: (*a*) squamous, (*b*) parabasal, (*c*) abnormal (Class III), and, (*d*) cancer (Class IV) cells. Pleural fluid: (*e*) histiocyte, (*f*) mesothelial, (*g*) cancer (Class V), and (*h*) two cancer (Class V) cells.

from the cervix uteri, even in the early preinvasive stage of cancer. The microfluorometric scanner described here is under development as an adjunct to the Papanicolaou technique (*5*) for the cytological diagnosis of cancer, in the hope that this instrument can be used to facilitate the large-scale screening of the population for neoplastic disease, particularly for cancer of the cervix in the early stages, when appropriate treatment will afford a high rate of cure.

INSTRUMENTATION

The microfluorometric scanner consists of the following components: (1) a constant source of the long-wave ultraviolet light, (2) an ordinary light microscope with an automatic mechanical stage, (3) a scanning disk (Fig. 1), (4) a photoelectric detector, and (5) a voltage pulse discriminator and counter. By means of this device, the fluorescent light from each cell *separately* and *successively* is permitted to fall on a photocell. A pulse of light energy derived from each cell is converted into a voltage pulse, which is amplified and analyzed in terms of its ability to activate an electronic counting circuit set to respond to a certain voltage input and to register thereby the presence of certain types of cells. For display the voltage pulse is also presented on the screen of a cathode-ray oscilloscope (Figs. 2, 3).

Fluorescence microscope. The source of illumination

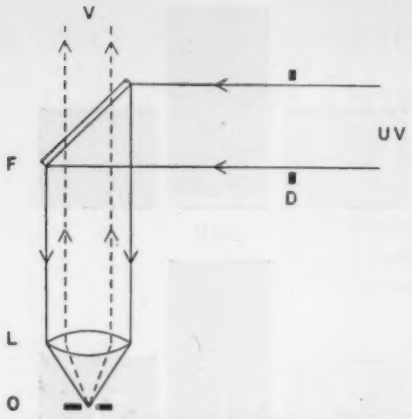


FIG. 4. Fluorescence microscope with vertical reflected illumination. Incident ultraviolet light, *UV*, reflected by special dichroic filter, *F*, and focused by objective, *L*, onto object, *O*, excites visible fluorescence, *V*, which is then transmitted through *F*.

is a mercury arc (G-E, Type AH-4), energized with a constant wattage transformer and monitored for constant light emission. The ultraviolet energy for the excitation of fluorescence is isolated by a filter (Corning C. S. 7-83) and consists of a band of about 40 mμ which has maximum energy at 365 mμ. The illuminator is fitted with a quartz lens (Fig. 2, L_1) and is used in accordance with the method of Köhler.

The microscope is of conventional design. For illumination with transmitted ultraviolet light the first surface of the substage mirror is aluminized. The optics of the microscope condenser (Bausch & Lomb) is glass, with minimum spherical abberration and numerical aperture 1.0; that of the objective (American Optical) is glass with numerical aperture 0.85, and magnification ×50. The depth of focus of the objective in the present application is ± 5μ.

A nonfluorescent filter, which absorbs the energy of excitation but transmits the fluorescent light emitted by the specimen, is placed between the objective and the detector. For fluorochromes, such as berberine, that emit in the yellow region, Corning filter C. S. 3-61 or Polaroid UV 420 are satisfactory, but for preferred dyestuffs that emit in the green or the blue regions, a satisfactory filter combination is not readily obtained because of the transmission by the source-filter of the strong emission lines of the mercury arc in the visible blue-violet region. For this and other reasons an investigation has been made of the potentialities of vertical reflected illumination by the use of a special dichroic filter[3] with high reflectance for the ultraviolet and low reflectance for the visible, and with transmission properties that are reciprocal to the reflectance (Fig. 4). The performance of this filter system is such as to make likely its adoption in the microfluorometric scanner.

[3] Obtained through the courtesy of A. F. Turner, Bausch & Lomb Optical Company, Rochester, N. Y.

Mechanical scanning. To scan the fluorescence of cells on a microscope slide it is necessary to allow the light emitted by each cell to fall *separately* and *successively* on the photosensitive surface of the photocell. The more practical choice between mechanical and electronic methods is a mechanical scanner[4] that utilizes a Nipkow disk (*6*) of the type used in the early work in television. The disk (Fig. 1) has a radius of 4 cm and contains a spiral of round apertures spaced at equal angular intervals so that only one aperture at a time is over the field or area being scanned. With one rotation of the disk, which at 1,800 rpm requires one thirtieth of a second, a scanning pattern is formed with a number of lines (20) corresponding to the number of apertures in the disk. The size of the apertures is equivalent in the object plane to a circle with a diameter of 10 μ, or of the order of a cell nucleus. The radial separation of the centers of the apertures corresponds to 5 μ in the object plane. Each scanning path therefore overlaps those adjacent on either side by 5 μ, so that all portions of the field are scanned.

The scanning disk is used in either of two positions—in the image plane, as in Fig. 2, or by optical

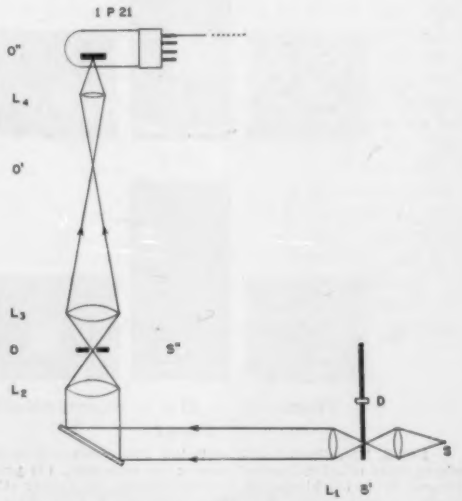


FIG. 5. Microfluorometric flying-spot scanner. *S*, source of critical illumination; *D*, scanning disk at image of source; L_4, ocular lens with high eye-point. Other symbols as in Fig. 2.

projection in the object plane, as in Fig. 5. When the disk is placed in the image plane, a conventional microscope field of about 0.2 mm diameter is illuminated. With one rotation of the disk the light from each self-luminous body in the field passes separately and successively through one of the scanning apertures and is focused on the photosensitive surface of the photocell. For a disk as described the linear

[4] We are indebted to M. G. Brown and M. L. Polanyi, of the American Optical Company, Stamford, Conn., for the principle of using the Nipkow disk in microscanning.

velocity of the apertures is 754 cm/sec, and the light impulse from a cell nucleus of average diameter, 10 μ, has a duration of 66 μsec.

When the flying-spot scanner is used (Fig. 5), the scanning disk is optically projected in the object plane. A flying spot illuminates the microscope field at any instant with a circular area of light 10 μ in diameter and scans the entire field in one rotation of the disk. Each object fluoresces separately and successively, and the light pulse therefrom is focused on the photocell for about 66 μsec. This system is preferred in terms of both mechanical and electronic performance and potentiality.

Aside from the scanning of a field, the microscope slide as a whole is scanned in a few minutes by means of an automatic mechanical stage,[5] which moves the slide back and forth in the x-direction and advances it intermittently in the y-direction.

Photoelectric detector. A lens (Fig. 2), which has as conjugate foci the image-plane of the microscope and the cathode of the photocell, produces a reduced image of the scanned, self-luminous body in the plane of the photosensitive surface. By this means the light energy passing through any scanning aperture during its entire transit falls on a small central spot of the photocathode, and variations in the sensitivity of the photocathode with position are minimized.

The detector is a type 1P21 photomultiplier tube (RCA), operating with a voltage of 675 v between the cathode and the last dynode and with 75 v per dynode stage. This affords a satisfactory signal-to-noise ratio.

The load resistance used with the photomultiplier tube is 5 megohms, which, together with the input capacity of the preamplifier that follows, produces a voltage pulse of somewhat longer duration than that of the light pulse of 66 μsec obtained in the scan of one nucleus with diameter 10 μ.

Preamplifier. A Type 9002 electron tube, which is connected as a cathode follower and used after the photomultiplier, serves as a preamplifier. This circuit reduces the capacitive load on the 1P21 tube and provides an output impedance that is low enough to permit the convenient use of several feet of cable between the output of the preamplifier and the input of the pulse-width discriminator. The amplitude of the voltage pulse at the cathode of the 9002 tube is of the order of 0.1–0.3 v, depending upon the type of cell scanned.

Pulse height-width discrimination. The discriminator circuit that follows the preamplifier performs two functions. First, a pulse-height discriminator rejects pulses that arise from cells with a lesser magnitude of fluorescence and at the same time passes pulses from cells with fluorescence energy above the level of interest and presumably in the range of diagnostic significance.

A second function of the circuit is to discriminate between pulses of different widths. This requirement must be met because the heterogeneous distribution of

[5] Designed by C. R. Stryker, of the Sloan-Kettering Institute.

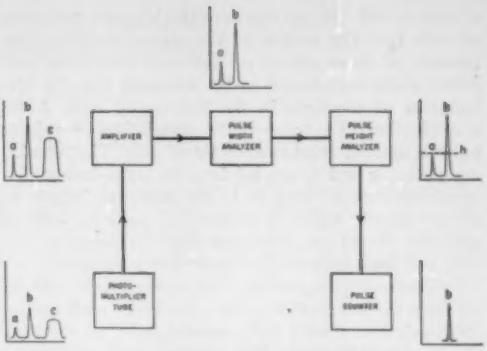


FIG. 6. Block diagram of electronic components of microfluorometric scanner. Voltage pulses of a normal cell, *a*, cancer cell, *b*, and a cell mass, *c*, are analyzed in terms of width (wide pulse *c* is rejected) and height (only pulse *b* is counted).

cells on a microscope slide is such that not only isolated cells but groups or clusters of cells occur. Such clusters, if compact and not optico-electronically resolved, give rise to pulses that are greater in height than those from individual cells. However, since the clusters are several cell dimensions in width, the associated voltage pulse is several times wider than that derived from a single cell, and such a pulse can be rejected electronically on the basis of width. For this a pulse-width discriminator passes a band of pulses with widths corresponding to those derived from nuclei of various sizes and with a range of diametric dimensions. In the present work this range is set at 10–18 μ, which is equivalent to a band pass of 66–119 μsec in the pulse-width discriminator. A pulse derived from a luminous object greater than 18 μ in diameter—i.e., of the order of twice that of two average normal nuclei—is rejected.

The final requirement which the circuit must satisfy is that the pulse-height and -width discrimination should proceed so that one operation does not electronically exclude the other. Further work on the design of circuits is required in order to fulfill this condition. The use in parallel of circuits for pulse-height and -width (7) discrimination, together with a coincidence circuit, may afford the simplest solution to the problem.

Pulse-counting. The output of the discriminator circuit is led into an amplifier (Tracerlab SC-15), which has a resolution time of less than 5 μsec and an input sensitivity of 1 mv. The output of this amplifier, derived from a multivibrator, is a negative pulse with a duration of 1 μsec and an amplitude of approximately 2 v. The output of the pulse amplifier is fed into a scaler (Tracerlab SC-100), where the pulses are counted at a maximum rate of 60,000 counts per minute.

The operation of the microfluorometric scanner composed of the foregoing components can now be summarized. Let one assume that the flying spot of illumination sweeps across a field which contains (Fig. 6)

a normal cell (*a*), a cancer cell (*b*), and a cluster of cells (*c*). The output of the photomultiplier tube consists of three pulses of differing amplitude and width which correspond to the intensity and the distribution of the light in the fluorescing cells. After amplification the pulse-width discriminator rejects pulse *c*, derived from the cluster of cells. The remaining pulses, *a* and *b*, are led into the pulse-height discriminator, whose level, *h*, is set above the height, *a*, of the normal pulse. A portion of pulse *b*, derived from the cancer cell, then energizes the counting circuit, and the presence of a cancer cell is recorded.

Oscilloscope presentation. The voltage pulse can be led from the preamplifier to a cathode-ray oscilloscope (Sylvania Model 400) for presentation on an observation screen (Fig. 2). The fluorescence and phase photomicrographs and the voltage pulses for various cells that exfoliate from the cervix uteri and the pleura are given in Fig. 3. The cytological criteria and the classification of Papanicolaou (*8*) are used. The voltage pulses are photographically recorded from the oscilloscope screen as each cell is scanned. Representative normal cells of the vaginal smear (squamous and parabasal epithelial cells) and of the pleural fluid (mesothelial cells and histiocytes) have voltage pulses of the order of 0.1 v. Cancer cells of the vaginal smear (Class IV) and the pleural fluid (Class V) have voltage pulses of 0.2 and 0.3 v, respectively. Abnormal cells (Class III) in the vaginal smear with morphological features suggestive of, but not conclusive for, cancer have intermediate values, of the order of 0.15 v. The fluorescence intensities of the cells in Fig. 3 are approximately representative of the average for samples of the order of 100 cells. The statistical evaluation of this material, which will appear in a forthcoming publication (*4*), indicates that 20 per cent of cells of Class III, 60 per cent of Class IV, and 83 per cent of class V have fluorescent light intensities above the maximum for the normal cells in a smear.

In view of the foregoing consideration, the development of a microfluorometric scanner for the automatic searching and detection of cancer cells in preparations of exfoliated cells appears to be feasible. This instrument, it is hoped, will serve as an adjunct to the Papanicolaou technique in the screening of the population for certain types of neoplastic diseases. Moreover, with modifications in technical and staining protocol to be described elsewhere, such an instrument has potential application in other fields: (*a*) clinical hematology, for the differential counting of cells of the peripheral blood and the bone marrow; (*b*) biology, in the counting of the relative numbers of resting, dividing, and polyploid cells in a fixed tissue culture, a spread of whole cells, or a preparation of isolated nuclei; and (*c*) radiology, for the study of the degenerative change in the nuclear chromatin of radiated cells that exfoliate from the serous and mucous membranes.

References

1. MELLORS, R. C. *Discussions Faraday Soc.*, **9**, 398 (1950).
2. MELLORS, R. C., PAPANICOLAOU, G. N., and GLASSMAN, A. *Cancer Research*, **11**, 267 (1951).
3. ———. *Am. J. Path.*, **27**, 734 (1951).
4. MELLORS, R. C., GLASSMAN, A., and PAPANICOLAOU, G. N. A Microfluorometric Scanning Method for the Detection of Cancer Cells in Smears of Exfoliated Cells (in preparation).
5. PAPANICOLAOU, G. N., and TRAUT, H. F. *Diagnosis of Uterine Cancer by the Vaginal Smear.* New York: Commonwealth Fund (1943).
6. ZWORYKIN, V. K., and MORTON, G. A. *Television: The Electronics of Image Transmission.* New York: Wiley, 216 (1940).
7. GERLACH, O. A., and SCHOVER, D. S. *Electronics*, **24**, 105 (1951).
8. PAPANICOLAOU, G. N. *Ann. Internal Med.*, **31**, 661 (1949).

Technical Papers

Series-Aiding Phototube Bridge[1]

L. G. Glasser

Engineering Department, Applied Physics Section, E. I. du Pont de Nemours & Company, Wilmington, Delaware

The series-aiding phototube bridge circuit, in conjunction with a light source, comprises a photometer that is ideally suited for measurements of light absorption with very high precision and sensitivity. The circuit schematically consists of a Wheatstone bridge arrangement of two resistors and two phototubes. The tubes are connected anode-to-cathode with a vacuum-tube voltmeter connected from a point between the resistors to the common connection between the phototubes. A small battery or dry rectifier can supply the bridge potential. In this circuit, the dynamic resistance of one phototube acts as a load resistance for the other phototube so that very large output voltages are obtained for small changes in relative light intensity on the tubes. Such a circuit measures the ratio of the light intensity on the two tubes and hence is independent of the intensity of the light source. When Type 935 phototubes are used, a sensitivity of 1 v for 1% change of light intensity is achieved when a total of 30 v potential is applied across the bridge. At 90 v the sensitivity is 7 v/%. Thus a high voltage is provided for a small change in light intensity. The vacuum tube voltmeter that operates in connection with this bridge must operate on circuit resistances ranging from 10^7 to 10^{13} ohms.

Best performance of the photometer employing this

[1] Abstract of a paper presented at the Gordon Research Conferences, New London, N. H., on Aug. 1, 1951.

circuit is obtained when the light intensities on the two phototubes are maintained at a constant ratio close to unity. Constant intensity ratio in an absorption photometer is achieved by employing a light gate to adjust the intensity in at least one of the light beams. When a light gate is employed, light absorption measurements can be made over the full range from 0 to 100% absorption. When a light gate is not employed and only the unbalance voltage of the bridge is measured, the range is restricted to 10 to 30% absorption, depending on the magnitude of the bridge potential. The calibration of the electrically unbalanced photometer is nearly linear over the useful range described, and the sensitivity drops off rapidly beyond this range. Measurements of light absorption with this circuit of the order of 0.001% can be reproducibly recorded.

The circuit is remarkably free from instability and drift. If the two phototubes have identical slopes and heights for the saturation portion of their characteristics curves, then when the relative illumination on the two tubes is maintained at a constant ratio, the output reading of the photometer is independent of bridge voltage. With commercial tubes, slight differences in slope and in height (or sensitivity) occur. The sensitivity difference is accommodated by using light intensities on the two tubes that are in inverse proportion to sensitivities of the tubes. The slope difference introduces a small voltage coefficient into the zero reading. This can be compensated by rapid trial-and-error selection of the relative values of the two bridge resistors.

A source of large drifts stems from the dependence of phototube response on absolute temperature. Although the effect is quite small by ordinary standards, it introduces errors when light absorption is measured over narrow ranges, such as 0 to 1%, or when stability over long periods of time, such as 24 hr, is required. The difference in the temperature coefficients of sensitivity between randomly selected Type 935 phototubes is often so large that a spurious absorption reading of 0.05% is introduced for 1° C change in temperature. This effect can be minimized by preselection of tubes, by thermal jacketing and temperature control, or by frequent zeroing of the photometer.

Major drifts and instabilities encountered in the use of this bridge are often caused by associated components. Changes in the color or color temperature of the source will unbalance the bridge, when the two phototubes have different spectral sensitivities. Many temperature effects may occur, including change in transmission of color filters, thermal expansion of mechanical members in the light paths, and drift of the voltmeter. Other sources of error are accumulation of dust at different rates on members in the two light beams, and accumulations of light-absorbing gases or vapors in different amounts in the two light paths. These difficulties can be minimized by good design of the apparatus, and the full capabilities of the series-aiding phototube bridge can be realized.

A Simple Instrument for the Determination of ACH[1]

J. B. Davidson[2]

Instrument Department,
Oak Ridge National Laboratory, Oak Ridge, Tennessee

The use of the contraction of the *rectus abdominus* muscle of the frog for the determination of acetyl choline is well known (*1*). The simple instrument described here eliminates the traditional smoked-drum kymograph and in its place uses a lightweight cantilever beam equipped with resistance wire strain gauges in a bridge circuit. The output of the bridge is recorded on a Brown strip chart recorder.

The strain gauges are of the paper kind (Baldwin Locomotive Works, Type A-7) and have a resistance of 120 ± .3 ohms and a gauge factor of approximately 1.92 ± 2%. Four of them are mounted on a Starrett feeler gauge which serves as the beam. The feeler gauge is of steel, 6″ long, ½″ wide, and .008″ thick. The width tapers from ½″ in the center to about ¼″ at one end. The beam is mounted between two pieces of brass of dimensions 4″ × 1″ × ¼″ (Fig. 1). About

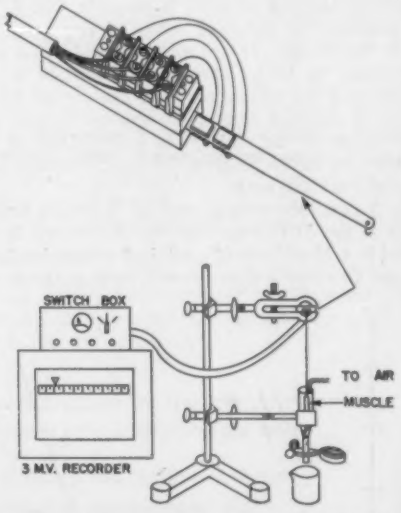


FIG. 1. Arrangement of strain gauge beam and frog muscle for ACH determination.

¼″ of the beam is clamped between the brass mounts. The four strain gauges are cemented to the beam (two on top and two on the bottom) ⅛″ from the clamped end, with Duco cement, according to the instructions of the manufacturer. After the gauges have dried thoroughly they are connected in a bridge circuit so

[1] Work performed under Contract No. W-7405-eng.-26 for the Atomic Energy Commission.

[2] The valuable suggestions and other aid given by Marian Stewart and C. W. Sheppard, of the Biology Division, are gratefully acknowledged.

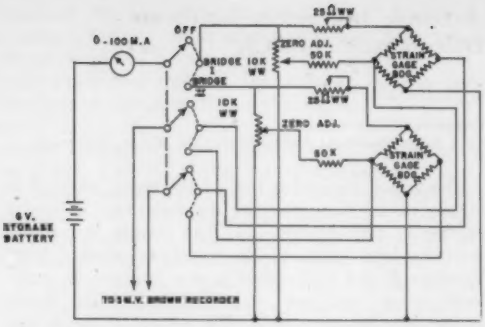


FIG. 2. Diagram of switch box for two strain gauge beams.

that the two gauges that will be in tension and the two that will be in compression are in opposite arms of the bridge. With the bridge connected in this manner maximum unbalance is obtained under strain. The use of four active gauges automatically provides temperature compensation. The leads from the gauges are extended with small flexible wires brought out to a terminal strip on the brass blocks, where connection is made through a four-wire cable to the switch box, the wiring diagram of which is shown in Fig. 2. This box provides for switching either of two beam outputs to the recorder. It also contains a 0–100-ma meter for reading the bridge currents, two balance or zero controls, and two current controls. The current for the bridges is supplied from a 6-v storage battery, normally set at 48 ma. This gives a sensitivity of 3 g full scale on the recorder, which has a voltage sensitivity of 3 mv full scale.

Fig. 1 shows the arrangement of the beams and the muscle in the ACH determination. The muscle is suspended in a 15-ml bath of eserinized amphibian Locke solution. One end is fastened to a hook in the bottom

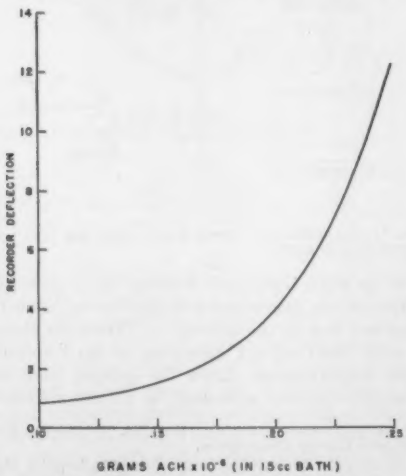


FIG. 3. Typical curve for *rectus abdominus* muscle.

of the bath, and the other by means of a silk thread to the end of the beam. Air is slowly bubbled through the bath at all times. When a solution is to be tested the Locke solution is drained by means of the pinch clamp and is replaced with the unknown. After the recorder reading has reached a maximum value the muscle is rinsed with the Locke solution and allowed to relax in the bath before the next determination is made. This requires 10–20 min. This relaxation may be speeded up by applying a small amount of tension to the muscle.

A typical curve is shown in Fig. 3. It should be noted that this method of determining ACH differs from the lever and smoked-drum method in that the latter keeps the muscle under a constant load (usually around 5 g) whereas with the cantilever beam the muscle is loaded by a spring. For purely analytical purposes, however, this difference does not influence the usefulness of the method described above.

Reference

1. GERARD, R. W., Ed. *Methods in Medical Research*, Vol. 3. Chicago: Year Book Pub., 87–88 (1950).

Barostat for High-Altitude Chamber

H. F. Brubach and H. Specht

National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, USPHS, Bethesda, Maryland

A large low-pressure chamber (9′ × 22′, including lock) for investigations at high altitude has been in use at this laboratory since 1942. In order to maintain accurately a given pressure level in the chamber during a run, it was necessary to readjust the controls occasionally because of the fluctuation in the pressure caused by the exhaust from air-operated apparatus being used in the chamber, occasional operation of the small medical lock, and drift up and down, which was due to the difficulty of accurately balancing the vacuum pump pressure against the ventilation bleed. Practically all the early use of the chamber has been with human subjects; consequently the pressure levels at which the chamber was operated were manually controlled, and continuous attendance was necessary. During the past few years, however, the chamber has been used for animal work which required long exposures (up to 24 hr) at various altitudes. In order to obviate the need for continuous manual control during these tests, a type of barostat was devised to control automatically the pressure level after it had been set manually.

The barostat (Fig. 1) consists of a 30-gal cylindrical steel tank (*A*) located outside the altitude chamber and connected with 1-in. pipe through the chamber wall (*B*) to the stationary side of a bellows within the chamber. The bellows (*C*) consists of two 9-in. metal disks in parallel position, over which is sealed a section consisting of 3 convolutions (*D*) cut from a large rubber bellows (type used in waterless metabolism

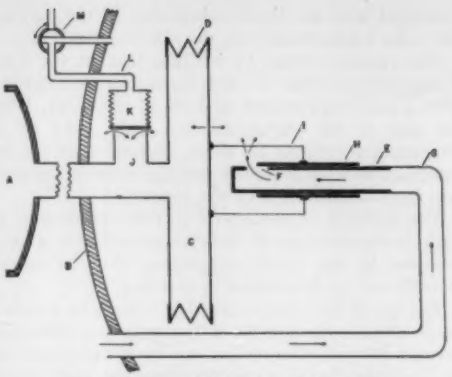


FIG. 1. Schematic drawing of barostat.

machines). In the relaxed position the metal disks are approximately 1½ in. apart. The pipe from the tank is sealed rigidly in a hole in the center of one disk of the bellows; the opposite disk is then free to move back and forth within the limitations of the rubber convolutions. Directly in the front and center of the movable disk of the bellows and at right angles to it is mounted a hard rubber or plastic tube (*E*) of approximately ¾ in. OD and ½ in. ID, with the end adjacent to the bellows occluded. A ½-in. hole (*F*) is drilled through the side of the plastic tube approximately 3/8 in. from the occluded end. The opposite end of the tube is sealed into a ½-in. pipe (*G*) which leads through the chamber wall to the outside. The OD of the plastic tube is machined so that it just turns or slides freely in the barrel of a 20-ml glass syringe. Both ends of the syringe barrel are cut off to produce a cylinder (*H*) approximately 3 in. long. This cylinder slides over the plastic tube and by means of a wire yoke (*I*) is flexibly linked to the movable disk of the bellows. The wires of the yoke are fastened to the glass cylinder by means of a plastic ring cemented to the cylinder. The wires are made of such a length as to have the glass cylinder cover half the side opening in the plastic tube when the bellows is in the relaxed position. A "T" (*J*) is placed in the 1-in. pipe between the bellows and the chamber wall and a small metal sylphon bellows (*K*) (approx 2" diam × 1½" length) is rigidly mounted directly over the open end of the "T." The closed, movable end of the sylphon bellows when it is in its relaxed position should be about ¼ in. from the open end of the "T." This end of the bellows is fitted with a rubber gasket which, when the bellows is expanded, forms a complete seal over the end of the "T." The stationary end of the sylphon bellows is connected by means of ¼-in. tubing (*L*) through the chamber wall to one leg of a three-way cock valve (*M*), or air switch, the second leg of which is connected back through the chamber wall and the third leg to the outside air.

Operation of the barostat is as follows. During the evacuation of the chamber the three-way valve is set, as indicated in Fig. 1, so that the pressure within the small bellows equalizes with that of the chamber and the bellows remains in the relaxed position. This allows equalization of the pressure in the chamber with that of the tank and the large bellows through the opening in the "T." The large bellows, remaining relaxed, maintains a static position of the glass cylinder over one half of the opening in the plastic tube, which allows a continuous flow of air into the chamber through this opening via the ½-in. line from the outside. When the desired altitude is reached and the chamber is "leveled off" as accurately as possible with the regular controls, the three-way valve is rotated clockwise a quarter turn so as to bring the small bellows into equilibrium with the outside or ground level pressure, which causes the bellows to expand and seal off the "T." The desired pressure in the tank and large bellows is thereby sealed off. A decrease in pressure within the chamber results in an expansion of the large bellows, which acts on the glass cylinder and causes it to move away, increasing the effective size of the tube opening. The resulting increase in air flow raises the pressure in the chamber. The reverse is true when for any reason the pressure in the chamber is increased. In this case a contraction of the bellows causes a closure of the tube opening, less air flow, and a consequent decrease in the chamber pressure. Before the pressure of the chamber is manually changed for any reason, the three-way valve must be in the position shown in Fig. 1. This is to prevent overexpansion or contraction of the bellows, since the opening in the plastic tube of the barostat can handle only a limited flow of air. This also places a limitation on the magnitude of the pressure changes it can correct. In our experience the ½-in. opening has been entirely satisfactory.

The dimensions given in this paper are for approximate guidance only, since they apply to the control of a specific apparatus. In general, the larger the opening at (*F*), the less sensitive will be the adjustment, and the larger the reservoir (*A*), the more sensitive will be the adjustment.

Determination of Radioactivity by Solution in a Liquid Scintillator

M. S. Raben and N. Bloembergen

New England Center Hospital and
Tufts College Medical School, Boston, and
Nuclear Laboratory,
Harvard University, Cambridge, Massachusetts

The fact that certain solutions emit light when exposed to an externally placed radioactive source (*1, 2*) suggested that a simple and geometrically ideal counting system might be obtained by dissolving the material to be counted directly in such a liquid. This method would facilitate particularly the counting of soluble compounds labeled with a weak β-emitter, such as C^{14}. The homogeneous distribution of the radioactivity and the virtually complete absorption of the

TABLE 1

COINCIDENCE COUNTING OF C^{14}-LABELED CAPROIC ACID DISSOLVED IN A LIQUID SCINTILLATOR

Sample	C^{14} (μc)	Counts/min		
		Uncorrected	Corrected for background	Noise background as % of signal
I Tube voltages 700 and 900				
(1) C^{14}-caproic acid in 0.5% terphenyl in xylene	.031	10,816	10,560	0.3
(2) As (1) + .45 mg cholesterol	.031	9,280	9,024	0.4
(3) As (1) + .45 mg dehydroisoandrosterone	.031	8,960	8,704	0.4
(4) 0.5% Terphenyl in xylene (background)	—	256	—	
(5) Emptied cell (noise background)	—	32	—	
II Tube voltages 750 and 940				
(1) Same as in I	.031	27,264	25,664	3.2
(2) " " " "	.031	24,128	22,528	3.7
(4) " " " "	—	1,600	—	
(5) " " " "	—	832	—	

emitted energy by the scintillator would solve the problems of geometry and self-absorption that make the usual counting methods technically difficult.

A narrow cell was improvised from flattened glass tubing and placed between the windows of two photomultiplier tubes (RCA 5819). A good optical contact between the cell and the windows was established with Canada balsam. The cell was 4 mm wide internally and 11 mm × 18 mm on its face sides, with 1-mm walls. A light-tight shield was put around the two photomultipliers and the cell. Fluid could be injected or removed through a small opening covered by black tape. The output pulses of the two photomultipliers were fed into linear amplifiers and discriminator circuits of conventional design. These were followed by a coincidence circuit with a resolving time of about 0.4 μsec, and the coincident pulses were counted by a 64-scaler, followed by a mechanical register.

Approximately ½ mg of C^{14}-labeled sodium caproate (7.28 μc/mg) in 0.5 ml of water was extracted with 2 ml of xylene after the addition of 2 drops of concentrated HCl. An aliquot of the radioactive solution was diluted 1:20 with a liquid scintillator, 0.5% terphenyl in xylene, and 0.45 ml of the diluted solution, containing 0.031 μc C^{14}, was injected into the cell to be counted.[1] Similar samples were counted that contained, in addition, nonradioactive steroids in a concentration of 1.0 mg/ml. The background was measured with the liquid scintillator in the cell, and the noise background with the cell emptied.

The results (Table 1) indicate that at the lower voltage 15% of the C^{14} disintegrations were counted with a noise background of 0.3% of the count. When the gain of the photomultipliers was raised by increasing the voltages by about 50 v, 37% of the disintegrations were recorded, but the noise background was increased to 3.2% of the count.

The addition of cholesterol to one sample and dehydroisoandrosterone to another caused only a small decrease in the count, suggesting that C^{14}-labeled steroids can be determined in this way.

The use of two photomultiplier tubes with a coincidence circuit resolved the difficulty in discriminating between the pulses caused by low-energy particles and the background pulses resulting from the dark current of the tube. The noise background, listed as (5) in Table 1, was caused by accidental coincidence of independent dark-current pulses from the two tubes. The more favorable signal-to-noise ratio was obtained with relatively low voltages on the tubes, but at a sacrifice in counting efficiency. To keep the counting efficiency constant, the requirements on the stability of photomultiplier voltage and gain of the linear amplifiers are rather stringent. The unduly high background count when the cell was filled with the liquid scintillator [(4), Table 1] may have been due to radioactive contamination of the apparatus or area.

It would appear from the results that the method is applicable to mμc amounts of C^{14}. The use of the method requires that the counting efficiency of a sample be determined by adding a radioactive standard to the sample after counting it, or by adding it to a nonradioactive duplicate of the sample.

It is possible that with a less restrictive solvent than xylene, such as dioxane, a larger number of compounds may be counted in this manner.

[1] The amount of C^{14} in the sample was determined by two standard methods, through the kindness of David Feller, Tufts College Medical School.

References

1. REYNOLDS, G. T., HARRISON, F. B., and SALVINI, G. *Phys. Rev.*, **78**, 488 (1950).
2. KALLMAN, H. *Ibid.*, 621.

A Recording Warburg Apparatus[1]

William Arnold, E. W. Burdette, and J. B. Davidson

Biology Division* and *Instrument Department*, *Oak Ridge National Laboratory, Oak Ridge, Tennessee

During the past 20 years the Warburg manometer and vessel have become standard instruments of the biologist and chemist. As two fine monographs (*1,2*) on the subject exist, we shall not discuss the directions for use, nor the method of calculating the results. We shall describe a simple and relatively inexpensive modification of the method that gives a graphical recording of the data.

[1] Work performed under Contract No. W-7405-eng.-26 for the Atomic Energy Commission.

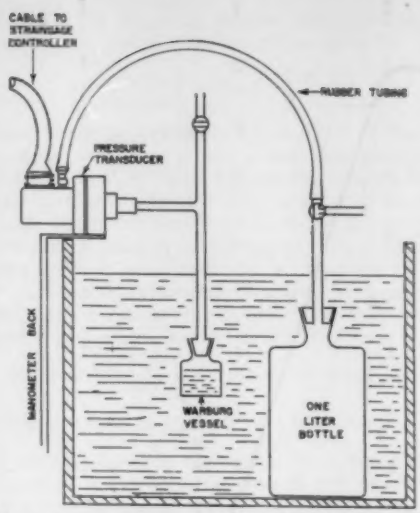


FIG. 1. Schematic diagram of transducer, vessel, and thermostat.

We are using the rectangular Warburg tank made by the American Instrument Company, substituting a mercury thermoregulator in order to have a constant temperature to about ± .02° C. We also use the standard vessels, round, rectangular, conical, with and without wells, etc. The shaking mechanism is used unchanged. The manometers have been replaced by pressure transducers (Statham Laboratories Model P5-O.2 D-125, ± 0.2 psi; cost, approximately $135). These are mounted on the tops of the old manometer backs and are provided with glass connections to the standard taper joints that hold the vessels and the stopcocks, just as are the regular manometers (Fig. 1). The pressure transducers can be shaken in a plane normal to their long axis without any effect on their response.

As the ventilating system in our building causes large and irregular changes in air pressure, we do not leave the backs of the pressure transducers open to the atmosphere, as is customarily done with regular manometers, but connect them with rubber tubing to a 1-liter bottle of dry air immersed in the thermostat. This procedure eliminates the need for the "thermobarometer" (Fig. 1).

The pressure range ± 0.2 psi covered by the transducer corresponds to 133 mm of Brodie's solution. The accuracy and linearity of about 1% of full scale are about the same as when using the regular manometer. The span switch in the controller circuit described below and in Fig. 2 makes it possible to change the range of the instrument at any time.

The strain gauge bridge circuit in the transducer is coupled into a transmitter and controller (Fig. 2) designed by C. A. Mossman, of Oak Ridge National Laboratory. The transmitter and controller contain a source of accurate adjustable voltage for the transducer, a "K" factor setting switch and helipot, a span adjustment, a zero adjustment, and calibration terminals for a calibration resistor. Accompanying each transducer is "F" (calibration factor of the individual transducer—i.e., the output voltage in mv due to a unit input of the variable with 1 v applied to the input terminals), which is multiplied by the pressure rating of the transducer to obtain the "K" factor to be set into the transmitter. The span switch allows the recorder scale to read 100% and 50% of the gauge rating, and the zero adjustment enables the recorder indication to be conveniently positioned on scale. A calibration resistor may be used with the transducer

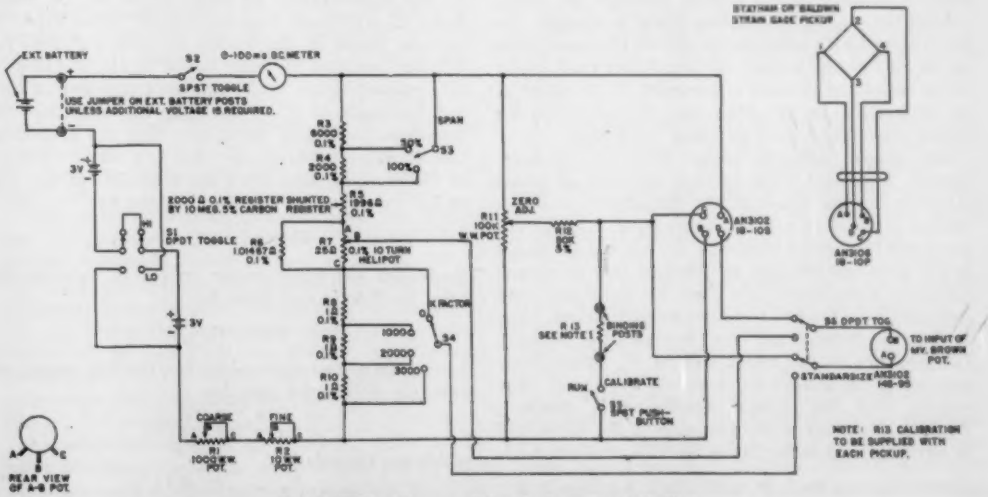


FIG. 2. Wiring diagram of the strain gauge controller.

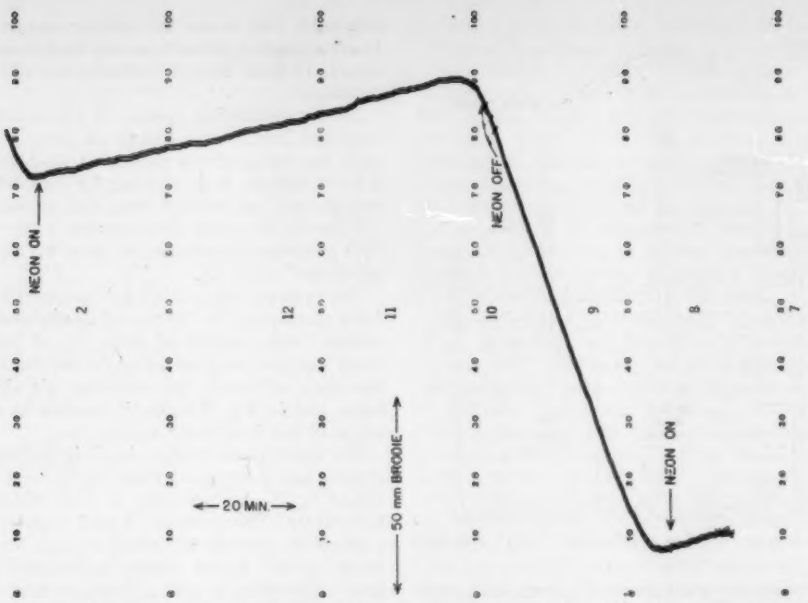


FIG. 3. Example of the performance of the recording Warburg apparatus (photograph of the Brown chart of an experiment in photosynthesis). Time runs to the left.

for the purpose of making an electrical check, which is equivalent to a pressure being exerted on the gauge. This is a means for periodically checking the accuracy of the gauge.

The large gas volume, approximately 6.5 ml, of the transducer head presented two difficulties. First, the gas space must be held to a constant temperature with the same accuracy as the vessel. This can be done by putting the transducer in a small copper box to which is soldered copper tubing. Through the tubing some of the water from the thermostat is pumped; the box is lagged with cellulose sponge. Or the same result can be obtained by putting the transducer much closer to the vessel and running it immersed in the water of the thermostat. In the latter case the cable and the Cannon connection must be made watertight.

The second difficulty comes from the pressure changes associated with varying amounts of water vapor in the gas space of the transducer. A hypothetical experiment will make this clear. Imagine the vessel and transducer filled with dry air and the liquid in the vessel covered with an infinitely thin membrane opaque to water vapor. We shake the vessel and head until they have reached temperature equilibrium. Then we close the stopcock and begin to record the pressure. The pressure in the vessel will be P_0, atmospheric pressure at the instant the stopcocks are closed. Now imagine that the opaque membrane is removed. Within a few seconds the gas space in the vessel will be saturated with water vapor, and the pressure reading will increase from P_0 to $P_1 = P_0 + \left(\frac{V_g}{V_g + V_h}\right) P_w$, where V_g = the volume of gas space in the vessel, V_h = the volume of gas space in the transducer, and P_w = vapor pressure of water, as one can show by making use of the gas laws. Water vapor will now slowly diffuse down the glass tube connecting the vessel and the transducer and the pressure will rise until the final pressure given by $P_\infty = P_0 + P_w$ is reached.

We can calculate the approximate time dependence of this pressure change in the following way: Let C = the concentration of water vapor in the transducer, C_0 = constant concentration of water vapor in the gas space of the vessel, $D = .239$ cm²/sec = the diffusion constant of water vapor in air, A = area of tube connecting the vessel and the transducer in cm², and L = length of tube connecting the vessel and the transducer in cm. If we assume that the concentration of water vapor in the tube is a linear function of distance, we have from the definition of the diffusion constant that the flow is given by

$$\text{Flow} = \frac{DA}{L}(C_0 - C).$$

Neglecting the water vapor needed to saturate the tube, the flow is also given by

$$\text{Flow} = V_h \frac{dc}{dt}.$$

Setting these two expressions for the flow equal, we have the differential equation

$$\frac{dc}{dt} + \frac{DA}{V_h L} C = \frac{DA}{V_h L} C_0,$$

which has the solution

$$C = C_0\left(1 - \text{Exp}\left(-\frac{DA}{V_h L} t\right)\right).$$

Of course, the change in pressure is proportional to C, so that the pressure change will be given by

$$\Delta P = \frac{V_h P_w}{V_g + V_h}\left(1 - \mathrm{Exp}\left(-\frac{DA}{V_h L}t\right)\right),$$

where ΔP is the additional pressure due to the diffusion of water vapor into a transducer originally filled with dry air. If we had started with the transducer partially saturated with water, the pressure change would not have been so large, but it would have had the same time dependence. When using the carbonate mixtures introduced by Warburg to hold the carbon-dioxide pressure constant, we have pressure changes connected with the diffusion of carbon dioxide that can be handled in the same way.

The quantity $\frac{V_h L}{DA}$ is a "relaxation time." It is the time that it takes to make all but $\frac{1}{e}$ of the total change. By making the tube connecting the vessel and the transducer a capillary, the area A can be made so small that the relaxation time will become 1 or 2 days, and thus an experiment can be completed before the pressure has changed very much. This is the method we used with the copper box described above and shown in Fig. 1.

We have also connected the vessel and transducer by a very short and a very large tube so as to make the relaxation time as short as a minute or so. We used this scheme when the transducer was immersed in the water of the thermostat. Either tube is satisfactory.

The Electro Products Laboratories make a transducer in which the gas space is so small that the diffusion effects are negligible, as they are in the ordinary liquid manometer; but, since the pressure in this instrument is measured by changes in capacity of a small condenser, one side of which is a thin diaphragm, radiofrequency methods must be used. The apparatus necessary to give a signal that can be recorded therefore becomes very expensive indeed.

Fig. 3 is a photograph of the Brown chart of an actual experiment. The vessel contained a thick suspension of *Chlorella* cells in carbonate buffer, so that only changes in oxygen pressure were measured. The light used was neon sign tubing. We see the oxygen production in the light due to photosynthesis and the use of oxygen by respiration in the dark. The time runs to the left on the chart.

References

1. Dixon, M. *Manometric Methods.* New York: Cambridge Univ. Press(1943).
2. Umbreit, W. W., Burris, R. H., and Stauffer, J. F. *Manometric Techniques and Tissue Metabolism.* Minneapolis, Minn.: Burgess Pub. (1949).

National Instrument Conference and Exhibit

From September 10 to 14, Houston, Texas, played host to nearly 7,000 scientists and technicians who attended the conference and exhibit sponsored by the **Instrument Society of America.** Other participating organizations were the Industrial Instruments and Regulators Division, ASME; Instruments and Measurements Committee and the Geophysical Technical Group, AIEE; American Institute of Physics; Institute of Radio Engineers; Scientific Apparatus Makers Association; National Association of Corrosion Engineers; Gulf Coast Spectroscopic Group; The Pipe Liners Club; A & M College of Texas; Research and Development Board; and the National Bureau of Standards.

In 27 technical sessions spread over the five days of the conference, the subjects considered ranged from general surveys of electron diffraction methods (W. O. Milligan) and infrared instrumentation (Van Zandt Williams) to descriptions of a new precision barometer (C. A. Heiland), instruments used in laboratory studies of corrosion (M. A. Judah), an electrical speedometer (J. J. Groncki), and the inevitable computers with their expanding uses (J. H. Curtiss, F. E. Brooks, Jr., Gregory Tobin).

As might be expected at a meeting deep in the heart of Texas, there was some preoccupation with problems peculiar to the petroleum industry. The Pipe Liners Club was concerned with the transmission of oil and gas; but other organizations less obviously interested in petroleum and its production sponsored programs, or panel discussions, or individual papers on "Physics and Exploration for Petroleum" (M. M. Slotnick, for the American Institute of Physics); on magnetometers (Walter Ruska, for ASME; L. J. Neuman, for AIEE); on refinery control problems (E. D. Mattix, for Texas A & M). Indeed, the titles of papers presented reveal a very lively and practical interest in oil from the time it is little more than a hope in the oil geologist's mind until it leaves the refinery, fractionated and ready for the most highly specialized uses.

To a considerable degree the flavor of the conference was reflected in the exhibit, which occupied 26,000 square feet of floor space in the Sam Houston Coliseum. More than 150 manufacturers displayed equipment that contributed much to the theme of the meeting—"Instrumentation and Our Security."

Developments in Europe were not overlooked, for A. O. Beckman, who was elected president of the ISA at the Houston meeting, addressed the members of the society on "The Instrument Industry of Europe." Other officers elected to vice presidencies at the meeting are D. Boyd, Universal Oil Products Co., and R. Sheen, Milton Roy Co. Continuing officers are W. A. Wildhack, National Bureau of Standards, vice president; N. L. Isenhour, Oak Ridge National Laboratories, vice president; G. R. Feeley, Trinity Equipment Co., treasurer; R. J. Rimbach, Instruments Publishing Co., executive secretary.

Comments and Communications

The Exponential Decay Law in Spray De-electrification

THE very interesting experiments of Czyzak and Williams (*1*) demonstrated that the potential of an electrified dielectric plate, against which is directed a uniform spray, decreases according to the relation $V = V_0 e^{-kt}$, where V_0 is the potential at zero time, t is the time, and k is a constant, depending on the material and the spray density.

An attempt was made to explain the data on the basis of discharging, which would occur when oppositely charged "carriers" in the spray deposit out on the plate. As the authors indicated, this leads to difficulties in explaining their results on charcoal sprays, for which the data are the most extensive.

Furthermore, if one assumes that all, or a constant fraction, of oppositely charged particles deposit, and that the spray does not change properties during an experiment, one is led to an expression of the form $V = V_0 (1 - K't)$, where K' is a constant proportional to the discharge current. This expression, analogous to the zero-order rate law of chemical kinetics, clearly does not fit the data.

Writing the empirical decay law in differential form, $dV/dt = -kV$ and substituting $Q = CV$, where C is the electrical capacity of the charged surface, and Q is the charge, one obtains $(1/C)\ (dQ/dt) = -kV$ or $i = -kCV$, where i is the discharge current. Thus, it is clear that in the experiments the efficiency of the discharge process is linearly proportional to the plate voltage.

This indicates that, if we wish to retain the charged carrier idea, a special assumption is required—namely, that the fraction of charged particles deposited varies linearly with the plate voltage. It appears unlikely that such a special law would be rigidly obeyed over the wide range of experimental conditions reported. For this reason, another mechanism, which requires no special adjustments to give a first-order rate law, is proposed here.

Let us assume that in the experiments which gave decay the initial charging in the spray is of negligible proportions compared to the high charge densities employed on the surface of the plate, and that, as appears plausible, some particles may escape after impinging on the plate. These particles will acquire a surface charge density proportional to the mean charge density, or the potential on the plate, and will carry away some of the charge on the plate. This leads to the equation

$$-\frac{dQ}{dt} = KV,$$

where K is a constant, depending upon the number of particles which strike the surface and carry off charge, and upon the effective surface area of the particles. Integrating this expression and substituting above leads immediately to the exponential decay law, with $k = K/C$.

The emphasis now is upon processes that occur at the surface of the collecting plate. If all particles striking the plate adhere to the surface, a negligible discharge rate will be observed. Such might easily have been the case in the experiments with water, carbon tetrachloride, and glycerin, and with starch on a positive surface. The data for acetone suggest that liquids do not always behave in this manner, and that further work on liquid sprays is required. In addition, the cleanliness of the collecting surfaces becomes a very important factor, and it should be carefully controlled.

The change in discharge rate which occurs when polarity is reversed, but other factors remain constant, presents an interesting problem. Such behavior would be expected if it were known that particles adhered more readily to a charged surface of certain sign, but no such data appear available. However, contact potentials certainly affect adhesion, and it is not difficult to see qualitatively how a surface charge could operate with or against the forces arising from contact surface potentials.

Further experiments are required to establish unequivocally the mechanism involved in this type of experiment, which has an important bearing on problems such as triboelectric charging of airplane surfaces (*2*), and the mechanism involved in the electrostatic particle counter (*3–5*). It is hoped that these suggestions will encourage further work in what has always been a difficult field.

CHESTER T. O'KONSKI
Department of Chemistry and Chemical Engineering
University of California, Berkeley

References

1. CZYZAK, S. J., and WILLIAMS, D. T. *Science*, **114**, 66 (1951).
2. HALL, W. C. *J. Applied. Phys.*, **18**, 759 (1948).
3. GUYTON, A. C. *J. Ind. Hyg. Toxicol.*, **28**, 133 (1946).
4. O'KONSKI, C. T. Ph.D. diss., Northwestern University (1948).
5. GUCKER, F. T., and O'KONSKI, C. T. *Chem. Revs.*, **44**, 373 (1949).

A Simple Sampling Device for Submerged Cultures

WHEN using a submerged culture fermenter for the small-scale production of antibiotic substances, it is necessary to take frequent samples to follow the progress of their formation. The device described here has been used for small-scale submerged cultures, 6–40 liters, and has been found to be a simple, contamination-proof system for sampling (Fig. 1).

Tube *A* enters the bottle and terminates in a perforated spiral. Air is forced through the opening at *A*, enters the medium through the perforated spiral, and

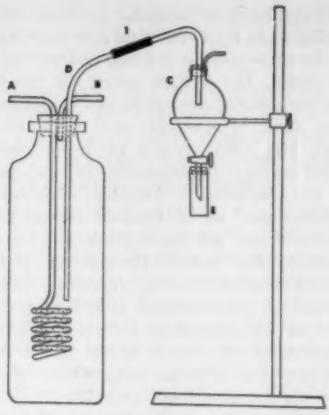


FIG. 1.

escapes at *B*. In operation, a screw clamp is placed at 1 to prevent passage of medium through tube *D*. In order to remove a sample, all that is necessary is to release the screw clamp at 1 and close the opening at *B* with the finger. The pressure created in the bottle will force culture medium through tube *D* into the separatory funnel *C*. When a large enough sample is collected in *C*, the finger is removed to release the pressure in the bottle. The sample may then be drawn off by placing a sterile test tube at *E*.

The aerator may be modified in size and shape to suit the investigator. This illustration merely indicates one type that may be used.

The entire apparatus is easily sterilized. The bottle with culture medium is plugged with cotton and autoclaved. The remainder of the apparatus is wrapped in paper and also autoclaved. When ready to use, the cotton stopper is removed from the bottle, the opening sterilized in the flame of a Bunsen burner, and the rubber stopper carrying the various tubes inserted firmly in place.

H. A. WALCH, JR.
G. J. JANN
A. J. SALLE

Department of Bacteriology
University of California, Los Angeles

Book Reviews

Industrial Medicine on the Plutonium Project. Survey and Collected Papers. Robert S. Stone, Ed. New York–London: McGraw-Hill, 1951. 511 pp. $6.25.

This recent addition to the "National Nuclear Energy Series" summarizes the evolution and development of the health programs for personnel associated with the three main units of the Plutonium Project—namely, the Metallurgical laboratory at Chicago, the Clinton laboratories at Oak Ridge, Tenn., and the Hanford Engineer Works at Hanford, Wash.

The first 285 pages constitute a survey section, which is preceded by an uncommonly interesting introduction. The ten chapters of this section include a description of the medical services of the Plutonium Project, a survey of past and present bases for maximal permissible exposure, and an account of the development and application of various chemical, physical, and hematological methods of monitoring on an individual basis for overexposure to the various harmful agents with which Plutonium Project workers might come in contact. Two chapters are devoted to an evaluation of certain biochemical studies (such as the excretion of chromogens, liver function tests, and the excretion of uranium) relative to their reliability as indicators of harmful overexposure.

The remainder of the book consists of collected papers that discuss, in more or less detail, studies relative to one or more of the chapters in the first section. In many instances the material in the "Papers" section actually forms the basis for the chapters in the first section. Because of this relationship there is considerable repetition throughout the book. Much of this is pardonable in light of the formidable problem inherent in editing the series, for in many instances the papers represent work done several years before publication by investigators who are no longer available to revise or edit their own papers. A few repetitions, however, where whole sentences or paragraphs are repeated (for example, sec. 9.3, chap. 4; sec. 3.3, chap. 5; sec. 9, chap. 4; and the last few sentences in chap. 5) are particularly distracting.

There is one unfortunate omission from the book—namely, the absence of any mention of the currently accepted tolerance dose of 0.3 r per week or equivalent for whole-body exposure to ionizing radiation. The various discussions are based on the older tolerance dose of 0.1 r per day, a value that was generally accepted at the time most of the chapters were written. A footnote or foreword would have been helpful.

The book is primarily of interest as a reference book for persons working in the field of industrial medicine or health physics and, as such, contains much material not otherwise readily available. In particular, it is a useful and readable source of information for the practical philosophy of health protection in radiation work. As a record of a contemporary adventure in preventive medicine the book is a tribute to the many medical and nonmedical per-

sonnel whose efforts made the Plutonium Project health program so eminently successful.

M. INGRAM

Department of Radiation Biology
School of Medicine and Dentistry
University of Rochester

Reports on Progress in Physics, Vol. XIV. A. C. Stickland, Ed. London: The Physical Society, 1951. 412 pp. £2 10s.

This volume continues the tradition established by earlier volumes of the series. It consists of 11 review articles on widely differing areas of current interest to physicists, 7 by British and 4 by American authors.

"Recent Advances in Ultra-Violet Absorption Spectroscopy," by W. C. Price (18 pp.), describes recent progress in the design and construction of photoelectric spectrophotometers. Most of the emphasis is on experimental techniques, such as cathode-ray presentation, color translation, high-intensity sources, and photographic emulsions, although there is also a brief review of interpretative work. "Anomalous Fine Structure of Hydrogen and Singly Ionized Helium," by W. E. Lamb, Jr. (45 pp.), starts with a thorough account of the experimental and theoretical history of the structure of the Hα line. The application of radiofrequency spectroscopy to the resolution of the problem by the author and his collaborators is described in considerable detail, and recent experimental and theoretical values for what is now universally known as the "Lamb shift" are quoted. An impressive feature of this work is the relatively large number of experimental techniques that had to be developed or improved, and the analysis that went into the consideration of each. "New Techniques in Optical Interferometry," by H. Kuhn (31 pp.), discusses recent work on the properties of optical surfaces and thin films, interference optics and spectroscopy, and testing methods. Several combinations of dielectric and metallic films are discussed, and a wide variety of applications, to such subjects as solar interferometry and interference microscopes, is briefly reviewed. "The Diffraction Theory of Aberrations," by E. Wolf (26 pp.), starts with a critical historical survey of investigations concerning optical image formation when aberrations are taken into account. Theoretical researches of the past decade, based mainly on expansions for cases where the wave deformation is a small fraction of a wavelength, are given particular emphasis, and several beautiful photographs are exhibited for comparison with the calculated aberration patterns. "The Spectrum of the Airglow and the Aurora," by A. B. Meinel (26 pp.), reviews recent progress in the observation of the night and twilight airglows, and of the aurora. The correlation of observed spectra with theoretical and laboratory results is discussed, and a few discrepancies are noted. Several problems of interest for future investigation, and the possibility of new experimental approaches, such as the use of microwaves and rockets, are mentioned.

"The Microphysics of Clouds," by B. J. Mason and F. H. Ludlam (49 pp.), deals mainly with the growth of water droplets and ice crystals induced by various kinds of nuclei. The authors point out the difficulty of simulating natural meteorological conditions in the laboratory, and the necessity for combining model, theoretical, and field studies of these phenomena. Several interesting photographs of ice and snow crystals are included. "Angular Correlations in Nuclear Reactions," by M. Deutsch (31 pp.), reviews work, mainly of the last 5 to 8 years, and the application of conservation laws to the relative angular distributions of successive nuclear reactions. The emphasis is placed on experimental techniques; the great complexity of the theoretical formulas precludes explicit mention of the theory in all but a few very simple cases. "The Nuclear Interactions of Cosmic Rays," by G. D. Rochester and W. G. V. Rosser (61 pp.), is an extensive review of all established types of nuclear effects produced by cosmic rays. These include evaporation stars, penetrating showers, the nuclear interactions of heavy nuclei, electron-photon mixtures, and mesons, and the transition effects of various combinations of these. In some cases, the various experimental techniques employed are illustrated by photographs. "Nuclear Effects in Atomic Spectra," by E. W. Foster (28 pp.), discusses mainly the results of optical investigations of hyperfine structure. The effects of nuclear mass and volume on the relative term values of different isotopes of the same element are presented from both theoretical and experimental points of view. The hyperfine structure caused by nuclear magnetic dipole and electric quadrupole moments is also considered, and the effect of the finite spatial extent of these moments is briefly discussed. "A Critical Survey of Ionospheric Temperatures," by N. C. Gerson (50 pp.), reviews temperature measurements by several different methods in the altitude range 100–400 kilometers. Quite good agreement is found, indicating the likelihood that thermal equilibrium and a Maxwell distribution of all atmospheric particles exist. Several directions for future research are indicated. "Some Applications of Nuclear Physics in Medicine," by W. V. Mayneord (47 pp.), summarizes the medical applications of radioactive isotopes produced by piles and cyclotrons, and also the therapeutic uses of fast electrons and gamma rays. Both radioactive sources and artificial accelerators are dealt with. Brief mention is made of high-speed neutrons, and there is a more extended discussion of high-energy x-rays. A concluding section emphasizes the vital importance of protection, and points out the difficulties attendant upon the establishment of "safe" dose levels.

The bibliographies appear to provide extensive and representative coverage of the literature. The publishers are to be congratulated on the appearance of the book, as regards typography of text and equations, line cuts, and plates.

L. I. SCHIFF

Department of Physics, Stanford University

Eyes and Industry. (2nd ed. of *Industrial Ophthalmology.*) Hedwig S. Kuhn. St. Louis, Mo.: Mosby, 1950. 378 pp. $8.50.

Eyes in Industry: A Comprehensive Book on Eyesight Written for Industrial Workers. Dorothy Adams Campbell, W. J. B. Riddell, and Sir Arthur Salusbury MacNalty. London–New York: Longmans, Green, 1951. 234 pp. $6.50.

Extensive use of mechanical power has lessened dramatically the demand on man's strength, and the skill of the workman is more and more being transferred to the machine. Sir Edward Appleton, Secretary of the (British) Department of Industrial Research, appropriately remarked, "It has been the custom for us to regard industrial workers as 'hands,' and we are accustomed to such phrases as 'hands wanted.' Nowadays, it would be more appropriate to say 'eyes wanted,' for workers are becoming more and more employed and paid for services whose main demand is on eyesight." This fact is reflected in the growing interest of several groups of specialists and of enlightened management in the most effective utilization and conservation of one of our precious resources—the human eyesight.

During each of the past three years there has been published an important contribution to the field of industrial ophthalmology. In 1949 it was H. C. Weston's *Sight, Light and Efficiency* (SCIENCE, 111, 432 [1950]). The following year Kuhn's *Industrial Ophthalmology* (1944) appeared in its second edition, enlarged by almost 100 pages and rechristened. In 1951 a group of British workers put out a book bearing an almost identical title. Whereas Weston is concerned principally with illumination and the experimental study of visual components of industrial performance, Kuhn approaches the problem of eyes in industry from the point of view of industrial ophthalmology as a specialty within the broader frame of industrial medicine. The British authors wrote for a nontechnical audience but covered all four major problems: provision of adequate illumination, environmental (such as brightness contrast) and optical aids to vision, suitability of particular eyes for particular jobs, and avoidance of industrial hazards to the eyes.

A. C. Snell, in his foreword to Kuhn's treatise, makes it clear that the demands made by modern industry on man's vision (and on the industrial ophthalmologist's skill and knowledge) are manifold. It is not just a matter of ocular traumatic surgery and prescription of lenses to correct defects of refraction. The visual abilities required by different jobs vary markedly. Sometimes it is a sharp visual acuity at a far or near distance, at other times an accurate color discrimination or a quick and reliable depth perception. These specific demands must be taken into account in visual testing in industry. Dr. Kuhn's close contact with the realities of the shop and the factory, documented by numerous pictures of industrial operations, and her association with the Department of Industrial Psychology at Purdue University, carrying on extensive investigations on vision in industry, are positively reflected in the 100-odd pages devoted to the problem of visual tests and standards and the 30 pages dealing with corrective programs. This section constitutes an outstanding feature of the book. The second large portion of Kuhn's volume is concerned with eye injuries caused by solid bodies (a chapter contributed by A. C. Snell), radiation and chemical agents, and with eye protection. Short chapters cover illumination (distribution of light, brightness contrast, color factors, intensity of illumination), and the blind in industry. A large number of references concerning the relationship between lighting and production are given, but the literature is not critically analyzed and synthesized. Only a few lines are devoted to the problem in the text.

The British collaborative publication is directed to management rather than to specialists in industrial ophthalmology, physiology, and psychology, and its nature is indicated by its subtitle "A Comprehensive Book on Eyesight Written for Industrial Workers." Its object is a practical one—better eyesight and better care of human eyes in industry. It covers much the same material as Kuhn's volume but provides more data on the anatomy and physiology of the eye. There are brief chapters on eyesight of adolescents, which stress the importance of visual abilities for vocational guidance; on eye defects common to adults; and on the "psychology of sight," devoted largely to the phenomena of illusion and hallucination, a matter which has little or no relevance to industrial vision. Two long chapters deal with eye injuries and their prevention, and with eye diseases in industry. These chapters overlap to a considerable degree, which is not uncommon in collaborative works but which indicates inadequate planning and insufficient editorial attention. Thus first aid is discussed in special subsections on pages 126–28 (chap. X), pages 167–69 (chap. XII), and again in Appendix I (pp. 195–99). If a second edition is to be issued, the unnecessary duplication should be eliminated. Appendix II contains a detailed schedule of values of illumination recommended in 1946 for the lighting of building interiors by the (British) Illuminating Engineering Society. Appendix III provides a useful summary of visual standards in the armed forces as well as for various occupations (e.g., police and railway employees).

JOSEF BROŽEK

Laboratory of Physiological Hygiene
University of Minnesota, Minneapolis

Association Affairs

The Association's Annual Exposition of Science and Industry

Raymond L. Taylor

Assistant Administrative Secretary

IN THEIR beginnings, exhibitions, fairs, or expositions must be as old as human society. It is natural, therefore, that displays of specimens, of techniques, and of products useful to scientists go hand in hand with the reading of papers and presentation of ideas at scientific meetings. Thus, during the 103 years of AAAS history, there has scarcely been a meeting in which individuals and institutions have not shown scientists in attendance the tangible results of their scientific work. In time, as the annual meetings of the Association grew larger, the exhibits were grouped together, and the exhibitors included manufacturers or distributors of books, instruments, and scientific supplies. Always, someone had to plan the exhibition and then make the necessary arrangements for it. At the 18th meeting of the AAAS at Salem, Mass., in August 1869, the *"Programme"* carried the request

> Microscopists will please confer with Mr. Bicknell as soon as possible after arrival, in relation to the exhibition of any instruments or apparatus they may bring. The room devoted to Microscopes is the Law Library in the *new* Court House. . . .

At this same meeting, there was a "demonstration of a remarkable case of malformation of the Thorax in a healthy living subject" and "interesting experiments of an electro-magnetic nature."

For many years, at each meeting, the exhibit manager was an interested and willing local member of the Association. At the 46th meeting, in Detroit (1897), planning and arrangements were entrusted to a six-man Committee on Exhibits, and the exhibition was assigned four rooms. New apparatus and inventions became regular features at AAAS meetings. At the 73rd meeting, in Chicago (1920), "a special Wireless Telephony Exhibit" was prepared by the American Telephone and Telegraph Company and the Western Electric Company and was staged under the auspices of the National Research Council. A Science Theatre showing the latest scientific films apparently had its inception at the 74th meeting, in Toronto (1921).

The *General Program* of the Boston Meeting of December 1922, was the first to list in advance an "Exhibition of Scientific Instruments and Materials." Among the eleven pioneer commercial exhibitors were the American Optical Company (Spencer Lens Company), Bausch & Lomb Optical Company, James G. Biddle Co., General Electric Company, and E. Leitz, Inc.—all of whom, it is gratifying to note, not only are still in business but will be present in the 1951 Exposition.

At the 78th meeting in Cincinnati, December 27, 1923–January 2, 1924, the arrangements for "The Exhibition of Scientific Apparatus, etc." were in the hands of Ralph E. Oesper, of the University of Cincinnati, and the show filled the laboratories of the Department of Physics. In the *General Program* it was said "It is hoped . . . that the annual exhibition of the AAAS may, in future years, attain national and even international prominence." There were 21 commercial exhibitors, including Leeds & Northrup, of Philadelphia, and seven local concerns.

The first AAAS Annual Science Exposition, as an *organized* activity, with many more commercial exhibitors, was held in conjunction with the 79th meeting, at Washington (1924). Charles A. Shull, of the University of Chicago, was manager, the exhibit area was the floor of the gymnasium of George Washington University, and W. J. Showalter of the *National Geographic Magazine* was in charge of all local arrangements. For the period 1925–30, H. S. Kimberly was the first of several persons to serve with the formal title of Director of Exhibits.

During World War II both the meeting and the exposition were suspended. Both were resumed, however, with the 112th meeting, at St. Louis, (March 1946). This exposition and those of December 1946 (Boston) and December 1947 (Chicago) were all large, attractive, and well attended. The Association's special celebration of its Centenary at Washington in September 1948, in the absence of any participating societies, had special scientific exhibits but no exposition. At New York in December 1949, however, the basic pattern of the Association's meeting and exposition was resumed, reaching a new high in the number and variety of exhibitors. In 1950, at Cleveland, the exposition attained what is considered its optimum size—150 booths and an exhibit area of 30,000 square feet, which permits adequate aisles and a lounge. In the arena of that city's well-designed Public Auditorium, book publishers, instrument makers, microscope manufacturers, and others who produce the tools of science were joined by several medical exhibitors and a number of large industrial concerns. The presence of medical and biochemical exhibits was logical, since a AAAS meeting has a high medical content in programs and attendance. (Medical researchers comprise one quarter of the Association's membership, and chemists almost another quarter.) The large industrial concerns, many of them local, took advantage of the opportunity to show some of their impressive technological accomplishments to an appreciative audience of research scientists and professional persons.

This year, at Philadelphia, the show has been retitled the Annual Exposition of Science and Industry, since this is more descriptive of its scope and objectives. It is a coincidence that 1951 will see the

inauguration of a new section, P—Industrial Science. From the following list of exhibitors who have already engaged booth space—and others whose arrangements are pending—it is evident that this outstanding exposition may equal the 150-booth limit set at Cleveland. The scientific population of Greater Philadelphia, added to those who come from virtually every state and province on the continent,[1] should provide an attendance worthy of this great total investment of time, thought, and manpower. No one who attends this year's Seventh Philadelphia Meeting should fail to see the exhibits during the four days, December 27–30, that they are open. Exhibitors who will participate are:

Books, Maps, and Publications

AAAS: SCIENCE, THE SCIENTIFIC MONTHLY	Washington
Academic Press Inc.	New York
Aero Service Corporation	Philadelphia
Association of American University Presses	New York
Biological Abstracts	Philadelphia
The Blakiston Company	Philadelphia
Encyclopaedia Britannica, Inc.	Chicago
D. C. Heath & Company	Boston
Houghton Mifflin Company	Boston
Lea & Febiger	Philadelphia
The Macmillan Company	New York
McGraw-Hill Book Company, Inc.	New York
G. & C. Merriam Company	Springfield, Mass.
The C. V. Mosby Company	St. Louis
National Geographic Society	Washington
Oxford University Press, Inc.	New York
Philosophical Library	New York
Prentice-Hall, Inc.	New York
The Ronald Press Company	New York
W. B. Saunders Company	Philadelphia
Science Library	Washington

Instruments, Laboratory Equipment, and Scientific Supplies

Ace Glass Incorporated	Vineland, N. J.
American Electronic Laboratories, Inc.	Philadelphia
James G. Biddle Co.	Philadelphia
Cambridge Instrument Company, Inc.	New York
Carolina Biological Supply Company	Elon College, N. C.
Fred S. Carver, Inc.	New York
Custom Scientific Instruments, Inc.	Arlington, N. J.
Fastax Division, Wollensak Optical Company	Rochester
General Chemical Division, Allied Chemical & Dye Corporation	New York
Harford Metal Products, Inc.	Aberdeen, Md.
Jarrell-Ash Company	Boston
Keystone Plastics Company	Swarthmore, Pa.
Leeds & Northrup Company	Philadelphia
Linguaphone Institute	New York
The Microcard Corporation	La Crosse, Wis.
New Brunswick Scientific Company	New Brunswick, N. J.
Nuclear Instrument & Chemical Corporation	Chicago
Phipps & Bird, Inc.	Richmond
RCA Victor Division, Radio Corporation of America	Camden, N. J.
Arthur H. Thomas Company	Philadelphia
W. M. Welch Manufacturing Company	Chicago

Medical

Allis-Chalmers Manufacturing Company	Milwaukee
Armour and Company, Research Division	Chicago
Difco Laboratories, Inc.	Detroit
Miles Laboratories, Inc.	Elkhart, Ind.
Sanborn Company	Cambridge, Mass.
Sharp & Dohme, Inc., Medical Research Division	Glenolden, Pa.
Sugar Research Foundation, Inc.	New York

Microscopes and Accessories

American Optical Company	Buffalo
Bausch & Lomb Optical Co.	Rochester
C. A. Brinkmann & Co.	Great Neck, N. Y.
Edmund Scientific Corporation	Barrington, N. J.
Ercona Corporation (Zeiss, Jena)	New York
The Graf-Apsco Co.	Chicago
E. Leitz, Inc.	New York
The Rayoscope Company	Delaware, Ohio

Technical Exhibits of Industries

The American Tobacco Company	Richmond
The Atlantic Refining Company	Philadelphia
Atlas Powder Co.	Wilmington
Chemstrand, Inc.	Decatur, Ala.
E. I. du Pont de Nemours & Co., Inc.	Wilmington
General Electric Company	Schenectady
Hercules Powder Company	Wilmington
Philip Morris & Co. Ltd., Inc.	New York
Polaroid Corporation	Cambridge, Mass.
Rohm & Haas Company	Philadelphia
Socony-Vacuum Oil Company, Inc.	Philadelphia

Special Exhibits

Human Resources Research Center, Lackland A F Base	San Antonio

[1] From 46 states in 1949 and from 47 states in 1950. For the geographical analyses of the registration at these meetings, see SCIENCE 111, 132 (1950); 113, 146 (1951).

News and Notes

Scientists in the News

Wallace F. Armstrong, a member of the Ethyl Corporation manufacturing department for the past 12 years, has been named manager of the company's new chemical plant now under construction near Houston, which is scheduled to go into operation next year. Mr. Armstrong will be in charge of the production of tetraethyl lead and the other special-purpose chemicals to be manufactured at the Houston facility.

Dugald Baird, Regius professor of midwifery at the University of Aberdeen, Scotland, will deliver the Cutter Lecture on Preventive Medicine at the Harvard Medical School on Oct. 15. Dr. Baird has chosen "Preventive Medicine in Obstetrics" as his subject.

The Institute of Radio Engineers has announced that the institute's medal of honor has been voted to **W. R. G. Baker,** vice president of the General Electric Company and general manager of its electronics division at Syracuse, N. Y. The board cited Dr. Baker for his "early technical contributions to the radio transmitter art, his long-sustained and effective leadership of institute and industry engineering groups and his outstanding service to the institute."

R. M. Barrer, of the University of Aberdeen, was visiting lecturer at the Iowa State College Institute for Atomic Research during the month of September. He delivered three lectures on researches on minerals, including: "Syntheses and Metamorphoses," "Ion Exchange," and "Sorption." **O. R. Frisch** also lectured on some of the nuclear physics work at Cavendish Laboratory, Cambridge.

Willard W. Beatty, chief of the educational branch of the Bureau of Indian Affairs, has become deputy director of the Unesco Department of Education. **P. W. Danielson,** assistant chief of the Indian Bureau's educational branch, succeeds him as acting chief.

Lester S. Blumenthal, clinical instructor in medicine at the George Washington University, attended the first congress of the International Association of Allergists, which met at Zurich. He presented a paper on "The Use of Ergot in the Treatment of Headache."

Philippe Boulin, engineer in the French Bureau of Mines, was a recent visitor at the U. S. Geological Survey.

Robert D. Calkins has been elected president of the Brookings Institution but will not assume his post until July 1, 1952, when **Harold G. Moulton,** who has been president of the institution since its inception, formally retires. Dr. Calkins has been director of the General Education Board, Rockefeller Foundation, since 1947.

Ian Campbell, of the California Institute of Technology, has been named chairman of the Industrial Minerals Division of the American Institute of Mining and Metallurgical Engineers. Professor Campbell, who is acting chairman of the Division of the Geological Sciences, will take office in February at the New York meeting of the institute.

W. Edward Chamberlain has been appointed 1951 visiting professor of oncology in the Cancer Research Institute of the University of California School of Medicine. Dr. Chamberlain is head of the Department of Radiology at Temple University Medical School and Hospital. His program includes lectures and medical conferences at both UC and Stanford Medical Schools.

Samuel A. Corson has been appointed professor of pharmacology in the Department of Physiological Sciences at the Kirksville (Missouri) College of Osteopathy and Surgery.

C. A. Coulson, professor of theoretical physics at King's College, London, has been appointed Rouse Ball professor of mathematics at Oxford to succeed E. A. Millne.

Richard S. Davidson, formerly assistant plant pathologist of the Ohio Agricultural Experiment Station, has been appointed plant pathologist and professor of botany and plant pathology of the Agricultural Experiment Station and the School of Agriculture of the Alabama Polytechnic Institute. Besides teaching Dr. Davidson will conduct research on diseases of peanuts.

Hilary J. Deason, chief of the Fish and Wildlife Service's Office of Foreign Activities since 1946, has resigned because of poor health. Dr. Deason joined the staff of the former Bureau of Fisheries in 1928 as an aquatic biologist at Ann Arbor, Mich. He has been active in whaling affairs since 1946, and returned in August from the third meeting of the International Whaling Commission at Capetown, where he served as deputy U. S. commissioner.

Wayne Dennis, of the University of Pittsburgh, has resigned to become head of the Department of Psychology at Brooklyn College, where he succeeds **Harry Helson,** who is now at the University of Texas.

Harry R. Gamrath has been appointed assistant director of research for the Organic Chemicals Division of the Monsanto Chemical Co. Dr. Gamrath went to Monsanto in 1934 as a chemist. During World War II, he was in charge of research for the Chemical Warfare Service plant operated at Monsanto, Ill.

Charles Garside has succeeded **Alvin C. Eurich** as acting president of the State University of New York. As a member of the board of trustees since the university was established in 1948, Mr. Garside has served

on the executive committee and as chairman of the committee on medical education centers. Dr. Eurich is filling an administrative position with the Ford Fund for the Advancement of Education (SCIENCE, **113**, 704 [1951]).

Seymour Levine, who at present is taking specialized training at the Cooperstown Laboratories, Cooperstown, N. Y., has been named instructor in biophysics in the Department of Biophysics at the University of Colorado Medical School. Prior to going to Cooperstown, Dr. Levine was a member of the faculty of Western Reserve University for two years.

A. Douglas McLaren has recently joined the staff of the University of California College of Agriculture as associate professor of soil chemistry. He will teach soil microbiology. He has been assistant professor of physical and polymer chemistry at Polytechnic Institute of Brooklyn.

The assistant secretary of the Royal Society, **D. C. Martin,** has been in Washington as a guest of the National Academy of Sciences–National Research Council. During his stay he gave an illustrated talk on "The Royal Society and Science in Britain." The National Research Council of Canada has invited him to visit universities in Canada.

John W. Moyer, chief of the division of motion pictures at Chicago Natural History Museum, has accepted an appointment in the foreign service of the Department of State. He will be engaged in the department's foreign information and educational fields and, after a brief stay in Washington, will leave for the Far East.

Edward N. Munns, since 1937 chief of the Division of Forest Influences in the U. S. Forest Service, has retired after more than 39 years' service. Mr. Munns served on the staff of the President's Water Resources Policy Commission last year and has served as vice president of the International Union of Forest Research Organizations and on the land committee of the Interstate Commission on the Potomac River Basin. He is a USDA representative on the Federal Inter-Agency River Basin Hydrologic Subcommittee, and is technical adviser on watershed management problems to the American Water Works Association.

Carl T. Nelson, professor of dermatology at Columbia University College of Physicians and Surgeons, has been appointed executive officer of his department. He succeeds the late **A. Benson Cannon.** He joined the teaching staff of the college and the clinical staff of the Vanderbilt Clinic in 1946.

James A. Oliver has been appointed curator of reptiles at the Bronx Zoo. Dr. Oliver is the zoo's third curator of reptiles in the 52 years of its history. His predecessors were **Raymond L. Ditmars,** who had charge of the snakes from the opening of the zoo in 1899 until his death in 1942, and **Brayton Eddy** (1945–50). Since 1948 Dr. Oliver has been an assistant professor in the Department of Biology of the University of Florida.

Richard U. Ratcliff, director of housing research for the Housing and Home Finance Agency, has resigned to return to his professorship at the University of Wisconsin. Dr. Ratcliff left the university on a year's leave of absence at the end of 1949 to set up the new HHFA housing research program authorized by the Housing Act of 1949. His leave was extended at the agency's request, and his service has now exceeded the period agreed upon. **Joseph H. Orendorff,** who has been serving as assistant director of the HHFA Division of Housing Research, as well as its chief of housing technology, has been named acting director of research.

Werner Richter has been elected rector of the University of Bonn in the capital of the Federal Republic of Germany. As one of the youthful statesmen of the Weimar Republic, Hitler forced his dismissal from Berlin. He found refuge in the U. S., lecturing at California, Wisconsin, and Yale universities. Reinhold Niebuhr found him a professorship of philosophy at Elmhurst College. He remained here until he was called to Muhlenberg College. Two years ago Bonn offered him the chair of philosophy, and he accepted. Bonn's philosophical faculty elected him dean two weeks before the election to the rectorship.

Mount Sinai Hospital has announced the appointment of **Jack Ruthberg** as assistant director. He had served continuously at Queens General Hospital for nine years, and before accepting his new appointment, he was deputy medical superintendent at the Queens institution, as well as assistant visiting physician at Queens General, Triboro, and Jamaica Hospitals.

The Ford Foundation has appointed **Robert Saudek,** vice president and assistant to the president of the American Broadcasting Company, as the director of its TV-Radio Workshop (SCIENCE, **114**, 289 [1951]). Mr. Saudek has resigned his present post at ABC, where he has been head of public affairs programs, sales development, and research.

A. C. van Dorsten, of Eindhoven, Holland, designer of the Philips electron microscope, is on a two months' lecture tour of the U. S. and Canada. He is scheduled to talk before scientific groups at Rockefeller Institute, Brookhaven National Laboratory, MIT, Columbia University, Notre Dame, Purdue, Rice Institute, and Oregon State University. He will also speak at the Electronic Physics Symposium to be held in Washington, D. C., and at the Electron Microscope Society meetings in Philadelphia in November.

F. S. Washburn, a board member of the American Cyanamid Company and director of its Agricultural Chemicals Division, has been elected president of the firm's Canadian subsidiary, North American Cyanamid, Ltd. He succeeds **H. P. Eastman,** who has retired. **E. D. Powers,** a vice president and director of the parent company, was elected vice president.

Education

Cornell University has adopted the "Spoken Approach," or Army, system of language instruction as a permanent part of its curriculum. The experimental program was underwritten for five years by the Rockefeller Foundation. Most of the undergraduates have been able to meet the university's language-proficiency requirements after the first year. A $20,000 modern language laboratory given to Cornell by the Gray Research and Development Company has enabled the university to turn out large quantities of authentic foreign language records, which have become increasingly important in the intensified method.

Applications for research space at the **Hawaii Marine Laboratory** for the summer of 1952 may be secured upon request to the director, University of Hawaii, Honolulu, T. H. They must be returned before *Feb. 1.*

A mechanics colloquium sponsored by **Illinois Institute of Technology** and **Armour Research Foundation** began on Oct. 3 with a lecture by S. J. Fraenkel and L. E. Grinter in a joint meeting with the American Society of Civil Engineers. Succeeding lectures will be held once each month through May 7 on the Illinois Tech campus, except for the May meeting, which will be at the Technological Institute of Northwestern University. Among the speakers will be W. Prager, A. Casagrande, L. E. Goodman, H. Ekstein, Arnold M. Kuethe, Dana Young, and Charles Lipson, in that order.

The Zoology Department of the **University of Illinois** has appointed Carl C. Clark assistant professor of zoology and has promoted Harvey I. Fisher to associate professor and James B. Kitzmiller to assistant professor.

The **University of Maryland** Institute for Fluid Dynamics and Applied Mathematics began a series of public lectures Sept. 25–27 with addresses by S. R. de Groot, of the University of Utrecht. The series will be continued by lectures on Nov. 13, 15, and 16 by R. W. Gurney, and on Dec. 11, 12, and 13, by J. Kampe de Feriet, of the University of Lille. All three are visiting research professors. Inquiries regarding the lectures, the program of the institute, and research positions and fellowships should be addressed to R. J. Seeger, director.

The **University of Puerto Rico,** through the Institute of Labor Relations, has begun an experiment in the teaching of English to a class of 125 Puerto Rican workers, chosen from more than 500 applicants. All the students attend classes after the workday is over. The methods and equipment developed by the Institute of Languages of Georgetown University are used, and if the project is successful the Insular government, through the Insular Economic Development Administration and Department of Labor, in cooperation with industry and federal agencies, hopes to place trained, English-speaking workers in mainland defense jobs.

The **University of Rochester** Cosmic Ray Group formerly headed by Bernard J. Peters has been placed in charge of Morton F. Kaplon, who was codiscoverer in 1949 with Dr. Peters and the late Helmut Bradt of the R-star, which provided the first clear-cut evidence of the production of large numbers of mesons in nuclear collisions of extremely high energy in the upper atmosphere. Charles Ritson, British physicist, is working with Dr. Kaplon, who is currently completing experiments at White Sands with unmanned balloons. Dr. Peters has gone to India to accept a special chair in cosmic ray research and teaching at Tata Institute for Fundamental Research.

The **World Health Organization** has granted the Department of Health of the Union of South Africa funds that will enable the following scientists to be sent overseas to study latest developments in their fields in Europe and the U. S.: R. Turner, pathologist, Cape Town; B. M. Clark, Pretorian health officer; B. J. van Rensburg, who will study tuberculosis control; H. Schiller, head of the venereal diseases section in Pretoria; L. A. Hurst, of the Weskoppies mental institution in Pretoria; and W. N. Taylor, of Fort Hare College, who will study sanitation.

Grants and Fellowships

Under a $20,000 **Air Force** grant, University of Texas chemists will try to develop an improved method for analyzing aluminum and steel alloys used in aircraft. G. H. Ayers is director of the project, and S. H. Simonsen is assistant director.

Supplemental **Fulbright** awards for university lecturing and postdoctoral research in European, Near Eastern, and Pacific areas have been announced for 1952–53. The closing date of the competition is *Oct. 15, 1951.* Fulbright agreements have been signed recently with Iraq, Denmark, and Japan, but programs have not yet been announced. Complete information may be obtained from the Committee on International Exchange of Persons, 2101 Constitution Ave., N.W., Washington 25, D. C.

American Telephone and Telegraph Company has announced the Frank B. Jewett postdoctoral fellowships in the physical sciences, which carry an honorarium of $3,000 to each fellow and $1,500 to the academic institution. Application blanks, returnable by *Dec. 1,* may be obtained from the Jewett Committee, Bell Telephone Laboratories, 463 West St., New York.

The **Twentieth Century Fund** has announced the assignment of Oscar C. Stine, former assistant chief of the Federal Bureau of Agricultural Economics, to appraise the government's farm program. The study will be conducted in Washington and is expected to take more than a year. M. R. Benedict, of the University of California, will be associated with Dr. Stine, who resigned from the USDA on August 31 after nearly 37 years of service.

In the Laboratories

Johns-Manville Corporation expects to finish this year the expansion of its Lempec, Calif., plant and mine. The diatomite deposit at Lempec is believed to be the largest in the world. Among relatively new uses for diatomite is the clarification of antibiotics.

McNeil Laboratories has appointed John F. O'Leary senior scientist in the Department of Pharmacology. An industrial chemist, Dr. O'Leary worked during World War II at the University of Rochester on a study of the toxicology of uranium, as part of the Manhattan Project.

Under joint sponsorship of the **University of Michigan Hospital** and the **National Foundation for Infantile Paralysis,** a respiratory center for extensive clinical research on polio will be opened at the hospital. James L. Wilson, chairman of the Department of Pediatrics and Communicable Diseases, will have overall supervision of the center, and David G. Dickinson will be director. Similar centers were opened last year at Children's Hospital of Boston, Wellesley Hills, Mass., and at Jefferson Davis Hospital, Houston.

Nicholas E. Golovin has been appointed assistant director for administration of the **National Bureau of Standards.** He will be concerned with the planning and administrative management of the technical programs of the bureau. Formerly executive assistant to the director, Mr. Golovin has recently been in California to activate the Corona Laboratories of the NBS. Lauriston S. Taylor, formerly in charge of the Radiation Laboratory, has been appointed chief of the Atomic and Radiation Physics Division and coordinator of Atomic Energy Commission projects at NBS. His work will involve the over-all direction of research programs in atomic and nuclear constants, electron physics, mass spectrometry, spectroscopy, radioactivity, x-rays, nucleonic instrumentation, high-voltage generators and accelerators, and evaluation of radiation hazards.

Jonathan R. Roehrig is now associated with **National Research Corporation** as a project manager in the company's Physics Research Department. He has been connected with the Submarine Signal Company and its successor, Raytheon Manufacturing Company.

Ralph E. Bowman will be head of the first **Parke, Davis & Company** oversea research laboratory at Hounslow, Eng., about 15 miles west of London. Dr. Bowman was formerly on the faculty of Birkbeck College, University of London. Parke, Davis is establishing a Latin-American headquarters at Colon, Panama, for the more efficient distribution of drugs in Spanish-speaking countries. The 85-year-old drug firm recently donated 10,000 doses of chloromycetin for hurricane relief in Jamaica, British West Indies, and Tampico.

Radio Corporation of America has elected Charles B. Jolliffe to the newly created position of vice president and technical director, and E. W. Engstrom as vice president in charge of RCA Laboratories Division. Dr. Jolliffe, who has been with RCA since 1935, will be responsible for long-range development and will direct the representation of the corporation in technical matters before public and governmental bodies. Dr. Engstrom was director of research of RCA for two years prior to his election in 1945 as a vice president. He had previously served the laboratories for 13 years in various research positions.

George K. Hawkins has been appointed to the staff of the Clinical Research Division of **Schering Corporation,** and Jeremiah A. Moynihan has been appointed to the Medical Service Staff. A native of Ireland, Dr. Moynihan was a resident surgeon at Doctors Hospital, New York, prior to joining Schering. Robert J. Bowie has been appointed assistant manager of the Schering International Division. He has had long experience in the marketing and promotion of pharmaceuticals in Latin America, Europe, and the Orient.

Sharp & Dohme has appointed four new research associates: Walter F. Charnicki, who received the Ph.D. from Purdue in 1951, to the staff of Pharmaceutical Research; John R. Corrigan, who has been with Sterling-Winthrop for the past two years, to the Chemical Development Department; Virginia Lytle, who received her M.A. from the University of Pennsylvania this year, to the Department of Virology; and Joaquin Munoz, who has been assistant professor of medical bacteriology at the University of Illinois, to the Bacteriology Department.

Wendell C. Peacock, one of the five original founders of **Tracerlab, Inc.,** has been elected vice president and technical director and a member of the board of directors. He has recently been on the staff of Sloan-Kettering Foundation and was chief of the Physics Department there when he rejoined Tracerlab last March as acting technical director.

Meetings and Elections

The **American Society for Engineering Education** elected the following officers at its annual meeting at Michigan State College: S. C. Hollister, of Cornell, president; M. M. Boring, of General Electric, and J. H. Lampe, of North Carolina State, vice presidents; and C. L. Skelly, of the Macmillan Company, treasurer. G. A. Rosselot and L. E. Grinter will continue as vice presidents.

Reginald J. S. Pigott, director of the engineering division of Gulf Research and Development Company of Pittsburgh, a subsidiary of Gulf Oil, has been nominated president of the **American Society of Mechanical Engineers.** He will take office at the end of the annual meeting in December, succeeding J. Calvin Brown, of Los Angeles, engineer and patent attorney.

The **American Society of Photogrammetry** will present Preston James, president of the Association of

American Geographers, Richard E. Harrison, cartographer to *Fortune* and *Life*, and Alfred O. Quinn, of Aero Service, Inc., in a symposium on the contributions of geography, cartography, and photogrammetry to areal studies, Oct. 11, in the auditorium of the Department of the Interior, Washington, D. C. Robert C. Campbell, head of the Department of Geography at George Washington University, will be moderator.

The 18th Christmas **Chemical Engineering Symposium** of the Division of Industrial and Engineering Chemistry of the American Chemical Society will be held at Northwestern University Dec. 27–28. The symposium will deal with nucleation, and there is room on the program for a few more papers. Attendance and participation are not limited to ACS members, but American nonmembers may not present papers unless a co-author is a member. Papers Committee chairman is C. M. Cooper, Du Pont Experimental Station, Wilmington, Del.

The **Council on Radio Journalism** has elected Baskett Mosse, of Northwestern University School of Journalism, chairman to succeed Floyd K. Baskette, who has served two successive terms. Robert K. Richards was re-elected secretary-treasurer. Kenneth H. Baker, director of research, has resigned to organize his own firm, Standard Audience Measurement Service, New York. The Council amended its by-laws to expand its membership from 10 to 12, providing for the addition of one industry and one educator member. One of the major functions of the council, which was formed in 1945 by joint action of the National Association of Radio and Television Broadcasters and the Association of Accredited Schools and Departments of Journalism, is an internship program in which radio journalism faculty members spend 10 to 12 weeks in the newsrooms of American broadcasting stations during the summer.

Genetics Society of America has elected the following officers for 1952: John W. Gowen, president; Roy E. Clausen, vice president; and M. R. Irwin, member of the Public Education and Scientific Freedom Committee (three-year term). Ernst Caspari, treasurer, and W. R. Singleton, secretary, continue in office.

At the meeting of the **International Commission on Illumination,** held at Stockholm last summer, Ward Harrison, consulting engineer, was elected president, first person from the U. S. to serve in that capacity in more than 25 years. All member countries were represented among the 540 persons at the conference, and Finland and Israel were new countries admitted. Central office of the organization, to be known as Committee International Eclairage (C.I.E.), will remain in New York, and meetings will be held hereafter at four- instead of three-year intervals.

The new president of the **International Union of Pure and Applied Chemistry** is Arne Tiselius, Swedish biological chemist who was a Nobel prize winner in 1948. Roger Adams, of the University of Illinois and 1950 president of the AAAS, was named a vice president-at-large, as were Endre Q. Berner (Norway) and Arthur Stoll (Switzerland). Vice presidents and section chairmen elected were E. W. R. Steacie (Canada), physical chemistry; Pierre Jolibois (France), inorganic chemistry; Paul Karrer (Switzerland), organic chemistry; C. J. Van Nieuwenberg (Netherlands), analytical chemistry; Leslie H. Lampitt (Great Britain), applied chemistry; and E. C. Dodds (Great Britain), biochemistry. The union, which will meet next year in Sweden, voted to readmit Japan and to grant membership to New Zealand and Western Germany.

The **World Medical Association,** meeting in Stockholm for its fifth congress, elected the Swedish physician Dag Knutson president for 1952, succeeding Elmer L. Henderson, of Louisville, Ky.

Miscellaneous

Chemicals wanted by the Registry of Rare Chemicals, 35 W. 33rd St., Chicago 16, Ill., are: potassium fluostannate; titanium difluoride; chromium carbonyl; tantalum silicide; trichlorogermane; 5-bromosalicylaldehyde; 4-amino-2-hydroxy-n-valeric acid; allylacetylene; 3,4-dihydroxyphenylacetic acid; N-acetylcystine; cis-aconitic anhydride; 2-chloropiperidone; 4-(3-hydroxyphenyl) butylamine; *p*-hydroxystyrene; 1,5-hexadiyne; D-mannuronic acid; opianic acid; leucylglycine; turanose; and thyronine.

Among new journals received by SCIENCE is the **Journal of Geomagnetism and Geoelectricity,** published in English by the Society of Terrestrial Magnetism and Electricity in Kyoto, Japan. Two issues were published in 1949 and three in 1950. It is planned as a quarterly. **Laboratoires** is a new quarterly review in French and English of French instrument and technical developments. The first issue appeared in the second quarter of this year. The first number of **Meteoros,** a quarterly of the National Meteorological Service, Buenos Aires, appeared in January 1951. **Vacuum,** an English quarterly, will review developments in vacuum research and engineering. The January 1951 issue (Vol. 1, No. 1) contained 27 pages of abstracts in addition to special articles. Other new journals announced, but not yet being published, include **The Journal of Rational Mechanics and Analysis,** to be published by the Institute for Applied Mathematics at Indiana University, and a multilingual **International Journal of Metal Science,** plans for which will be completed at the World Metallurgical Congress in Detroit this month.

The Society of Automotive Engineers (Detroit Section) has announced the Henry Ford Memorial Award. Any SAE member under 33 years of age is eligible to compete. Competition is by means of original papers that have been presented to, or are suitable for presentation to, an SAE meeting. Members interested in the competition may write directly to the Detroit Section, Society of Automotive Engineers, 100 Farnsworth, Detroit 2, Mich.

STATISTICAL METHODS FOR CHEMISTS

By W. J. YOUDEN, *National Bureau of Standards.* This book presents the modern system of units for expressing scientific conclusions. It combines the modern concept of experimental design with the associated techniques for the interpretation of data, using examples based on actual data from real investigations. Written from the laboratory man's viewpoint, it describes techniques useful in a wide variety of scientific investigations. *1951. 126 pages. $3.00.*

ULTRAVIOLET SPECTRA OF AROMATIC COMPOUNDS

By ROBERT A. FRIEDEL and MILTON ORCHIN, both at *Bureau of Mines.* Here are approximately 600 ultraviolet spectra, all plotted with uniform coordinates. The emphasis is on polynuclear hydrocarbons, but heterocyclic and polynuclear compounds with functional groups are also included. The text material deals with the application of ultraviolet spectra to the qualitative and quantitative analyses of chemical compounds. *1951. Approx. 618 pages. Spiral bound. Prob. $10.00.*

ORGANIC SYNTHESES, VOLUME 31

Edited by R. S. SCHREIBER, *Upjohn Company.* The latest of these reliable, valuable volumes contains 40 new syntheses. For almost 30 years these books have been successful guides to convenient, pretested laboratory methods for preparing various organic chemical reagents in one-half to five-pound lots. Each method can be adapted to large scale development. *1951. 122 pages. $2.75.*

FINITE DEFORMATION OF AN ELASTIC SOLID

By FRANCIS D. MURNAGHAN, *Instituto Technológica de Aeronáutica, Brazil.* The principal feature of this book is the consideration of squares and higher powers of the strain components in the theory of elasticity. This treatment permits the application of the theory to larger deformations and stresses than those allowed by the classical theory. A volume in the WILEY APPLIED MATHEMATICS SERIES, I. S. Sokolnikoff, Editor. *1951. 140 pages. Prob. $4.00.*

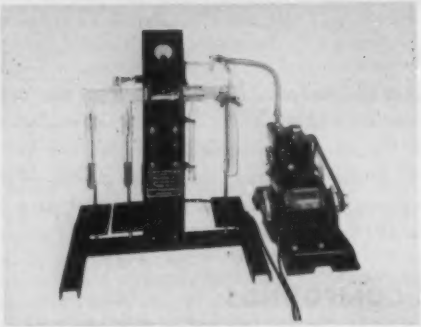
FLUORINE AND ITS COMPOUNDS

By R. N. HASZELDINE and A. G. SHARPE, both at *University of Cambridge.* Written for the non-specialist, this book presents a compact and well-integrated introduction to fluorine chemistry. The history and occurrence, preparation, and physical and chemical properties of fluorine and its compounds are covered systematically and thoroughly. This is one of METHUEN'S MONOGRAPHS ON CHEMICAL SUBJECTS. *1951. In press.*

Send today for your on-approval copies.

JOHN WILEY & SONS, Inc. **440 Fourth Avenue, New York 16, N. Y.**

HISTOLOGICAL FREEZE-DRYING APPARATUS, MODEL FD-11



- New simplified design—easy manipulation
- Built in vacuum circuit, infiltration equipment
- Superior Histological, Cytological results
- Essential for Histochemistry, Radioautography

Price—complete with accessories—$575
f.o.b. Cambridge, Mass.

For Latest Bulletin, write:

SCIENTIFIC SPECIALTIES CORP.
1955 Mass. Ave. Cambridge 40, Mass.

Recent Publications
CARNEGIE INSTITUTION OF WASHINGTON
1530 P Street, Northwest
Washington 5, D. C.

Publ. No.

175 Vol. VII–C. Parkinson, W. C., F. W. Wood, W. E. Scott, and Ella Balsam. **Magnetic Results from Watheroo Observatory, Western Australia.** (Department of Terrestrial Magnetism, Carnegie Institution of Washington, January 1945–June 1947; Australian Commonwealth, Bureau of Geology, Geophysics, and Mineral Resources, July–December 1947.) 1951. Quarto, v + 127 pp., frontispiece, 121 tables. Paper, $0.75; cloth, $1.50.

175 Vol. X–C. Ledig, P. G., A. A. Giesecke, Jr., W. C. Parkinson, W. E. Scott, and Ella Balsam. **Magnetic Results from Huancayo Observatory, Peru.** (Department of Terrestrial Magnetism, Carnegie Institution of Washington, January 1945–June 1947; Instituto Geofísico de Huancayo, July–December 1947.) 1951. Quarto, v + 127 pp., frontispiece, 120 tables. Paper, $0.75; cloth, $1.50.

586 Spoehr, H. A., J. H. C. Smith, H. H. Strain, H. W. Milner, and G. J. Hardin. **Fatty Acid Antibacterials from Plants.** 1949. Octavo, iii + 67 pp., 16 figs. Paper, $0.50; cloth, $0.75.

Demerec, M., and B. P. Kaufmann. **Drosophila Guide: A Guide to Introductory Studies of the Genetics and Cytology of Drosophila melanogaster.** With an appendix containing a series of experiments to be conducted by the beginning student. 1940. Fifth edition, 1950. Octavo, iii + 44 pp., 14 figs. Paper, $0.25.

A complete catalogue, or subject lists in archaeology and anthropology; astronomy and astrophysics; botany, ecology, and climatology; chemistry and physics; embryology; genetics; geology and geophysics; history, economics, and history of science; literature; mathematics; medicine; nutrition; paleontology; and zoology will be sent upon request. Orders may be placed direct or through regular dealers.

nuclear INSTRUMENTATION *for Use with* CARBON 14

MODEL 2611 COUNT RATE METER

Portable, efficient meter, designed for detecting Carbon 14, Sulfur 35, and other soft radiation sources. Thin mica end-window probe, will also serve for use as gamma survey meter. One-hand operation. Life of G-M counter unlimited by use.

● Work with radioactive compounds, labeled with Carbon 14, requires the full advantages of sensitive, versatile NUCLEAR instrumentation. Matched NUCLEAR units provide all radioactivity requirements from portable count rate meters to complete laboratory radioisotope analysis devices.

Instruments briefly described here are only part of the complete NUCLEAR line. Write for Catalog K, which contains complete data on all NUCLEAR instruments for use with Carbon 14.

MODEL 1615 "RADIATION SENTINEL"

Laboratory monitoring of alpha-beta-gamma radiation is the NUCLEAR "Radiation Sentinel's" job. Use for contamination checks of clothing, benches, glassware and hands. Suitable for continuous monitoring of background, chromatograms, air contamination or isotope decay. Can be used with chart-type recorder for continuous records.

nuclear INSTRUMENT and CHEMICAL CORPORATION
237 W. Erie St., Chicago 10, Ill.
Cable Address: Arlab, N. Y.
Export Department:
13 E. 40th St., New York, N. Y.

nuclear "PRECISION INSTRUMENTATION FOR NUCLEAR MEASUREMENTS"

- Scaling Units for Every Type of Radiation Counting
- Complete "Packaged" Counting Systems
- Health Monitoring Instruments for Personnel Protection
- Glass Wall, Mica Window, and Windowless Counters
- Portable Count Rate Meters
- Radioactive Chemicals
- Complete line of Accessories for the Nuclear Laboratory

Co-operation with Schools to Stimulate Interest of Graduate Students

To gain valuable industrial experience before starting to study for his Doctor's degree, Robert D. Haberstroh worked at the Westinghouse Research Laboratories during his 1950 vacation. He is shown preparing to run a test on a combustion chamber for a gas turbine. Mr. Haberstroh, a native of Johnstown, Pa., was graduated under the George Westinghouse Scholarship Program from Carnegie Institute of Technology last year with a Bachelor's Degree in mechanical engineering.

For more than half a century, Westinghouse has placed major emphasis on co-operating with educational institutions in the process of building men for positions of leadership. It was a pioneer in providing orientation and training programs for newly employed college graduates and in offering all employees opportunities for advanced degree work in co-operation with local universities. It has also been a leader in encouraging higher education in science and engineering through a large-scale program of scholarships and fellowships.

One of the latest additions to this broad program is a plan to co-operate with engineering schools in their advanced work by supplementing technical training with actual research experience.

Through this plan, selected students in graduate schools who are interested in the field of research are given the opportunity to get practical laboratory experience. During summer months, 10 outstanding students selected from engineering schools are given the opportunity to gain experience in the Westinghouse Research Laboratories.

Working beside seasoned research people, these young scientists gain firsthand experience in industrial research practices and techniques. Besides gaining much practical experience and valuable counsel, they earn while they learn.

Through this co-operation with colleges, Westinghouse hopes to aid students in choosing the scientific field they should enter, and, at the same time, strengthen their foundation for graduate school work.

Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. G-10138

YOU CAN BE SURE..IF IT'S Westinghouse

NO ROOM FOR DOUBT . . .

yet year after year laboratory projects prove to be inconclusive because of inconsistent and undependable reagents. For more than 11 years CARWORTH FARMS has been experimenting with newer and more advanced methods of improved guinea pig complement production and

"VACSEAL" *Guinea Pig Complement*

represents the culmination of these many years of efforts.

Our large output enables us to pool the serum of no less than 11 guinea pigs per lot, assuring the highest titer uniformity.

"VACSEAL" is packaged in high vacuum all glass containers. It is distributed in three sizes with a special diluent for restoration to the following amounts:

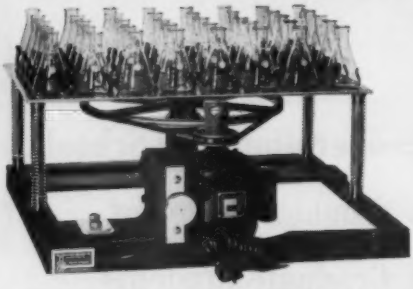
3cc. 7cc. 20cc.

For further information please write to:

CARWORTH FARMS, INC. • NEW CITY NEW YORK

Rotary Action

FLASK SHAKER



- Smooth operating, non-creeping and vibration free.
- Variable speed control . . . 160 to 400 oscillations per minute.
- Precision built for continuous operation.
- Versatile for experimentation, research or production.

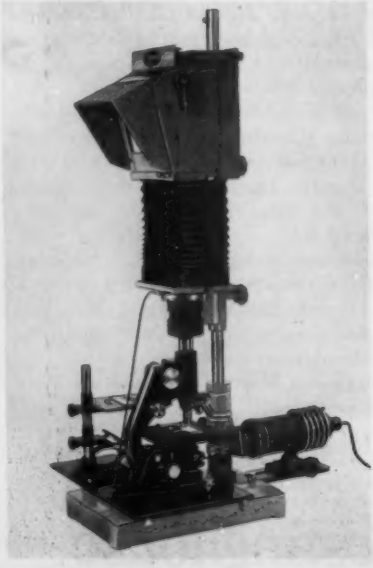
PRICE $379.50 · · · F O B NEW BRUNSWICK, N. J.

Detailed information available upon request.

NEW BRUNSWICK SCIENTIFIC CO.

PRECISION LABORATORY APPARATUS

10 HIRAM STREET • NEW BRUNSWICK, N. J.



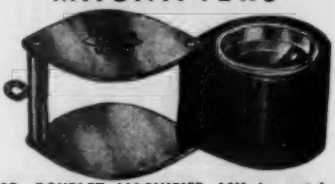
DON'T BUY A LABORATORY OR MICRO CAMERA BEFORE YOU HAVE INVESTIGATED THE GAMMA "MOD. U"

MORE UNIQUE FEATURES AT ***LESS*** COST. ASK FOR FOLDER GI-27 S

GAMMA INSTRUMENT CO., INC.

P. O. BOX 532
GR. NECK, N. Y.

MAGNIFIERS



No. 19F—DOUBLET MAGNIFIER 10X in metal mount $3.25 each

No. 21A DOUBLET 10X $2.75 each

No. 19 TRIPOD MAGNIFIER 10X $1.00 each

No. 19A Single lens in folding bakelite mount $0.50 ea.

THE GRAF-APSCO COMPANY

5868 Broadway Chicago 40, Ill.

PC

Immediately Available for Research Investigators

GELATIN GLUTATHIONE

- For intravenous use as a blood extender in shock burns, radiation injury, severe depletions of fluid and toxic infections.
- As a new field for investigation in rheumatic fever, arthritis and in ACTH induced diabetes.

Gelatin in hydrolysis is well known to yield a non-antigenic product. Glutathione is the tripeptide of the three amino acids glycine, cysteine and glutamine used in biologic detoxifications. Glutathione increases the osmotic pressure of gelatin 20% and inhibits syneresis (ageing of colloids) thus advancing gelatin usefulness.

Supplied in 500 cc vials, sterile, ready for use intravenously containing 6% gelatin (knox) and 0.5% glutathione S H (reduced form) or S S (oxidized form) as desired.

Bibliography on Request U. S. Patent #2,110,178

PHYSIOLOGICAL CHEMICALS CO., INC.

3 LE FEVRE LANE, NEW ROCHELLE, N. Y.

BIRD V-H KYMOGRAPH

CONTINUOUS feed . . . used for vertical and horizontal recording.

While designed for 10-inch paper this Bird Kymograph will feed narrower widths.

Eight speeds are provided giving paper speeds from 2 to 450 cm/min.

Precision of paper movement is not affected by use or non-use of take-up roll because separate motors are employed.

The Bird Kymograph V-H is furnished with an attractive aluminum and cast iron stand which has a handle at top for easy carrying.

In addition a six foot rubber covered cord and plug are provided.

WRITE TO:

Phipps & Bird INC.

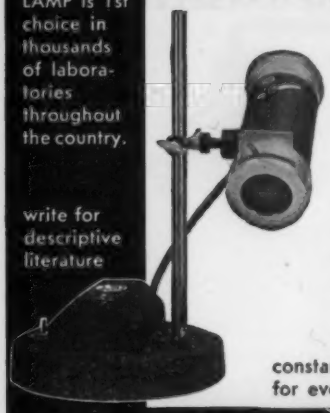
MANUFACTURERS • DISTRIBUTORS

RICHMOND, VIRGINIA

versatile efficient convenient, the E & G LAMP is 1st choice in thousands of laboratories throughout the country.

write for descriptive literature

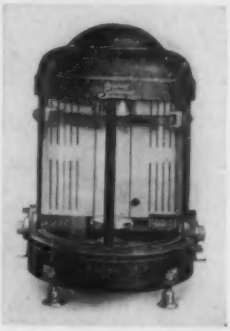
the E & G microscope lamp



designed to the specific requirements of the clinical, control and industrial laboratories, the E & G LAMP provides *controlled* illumination, cool operation, and constant, bright light for every application.

Erb & Gray

854 so. figueroa street
los angeles 17, calif.



SELECTA

FASTEST
MOST
CONVENIENT
SARTORIUS
ANALYTICAL
BALANCE

ALL WEIGHTS to 200 g. BUILT IN AUTOMATIC INDICATION OF END RESULT.

INSTANT DAMPING
IMMEDIATE DELIVERY

C. A. BRINKMANN & CO.
P. O. BOX 532
GR. NECK, N. Y.

A PARTIAL LIST OF

HELLIGE SPECIALTIES

COLORIMETERS
VISUAL AND PHOTOELECTRIC

COLORIMETRIC COMPARATORS
For Hydrogen Ion Measurements; Water Analyses; Color of Varnish and Lubricating Oil; Alpha-Amylase Dextrinizing Test; Lead in Air and Gasoline; Nickel in Plating Solutions; Chromate in Refrigerating Brines; Determination of Blood Sugar, Renal Function, and Plasma Volume; etc.

HEMOMETERS
Hellige Sahli and Color Disc Models

HAEMACYTOMETERS
BLOOD DILUTING PIPETTES • COVER GLASSES

BLOOD SEDIMENTATION APPARATUS AND ACCESSORIES

HELLIGE VISCOMETER
An Improved Blood Viscosimeter

GLASS ELECTRODE pH-METER

HELLIGE-TRUOG SOIL TESTERS

MICRO COVER GLASSES
CULTURE SLIDES • GLASS CELLS • GLASS RINGS

WRITE FOR
DESCRIPTIVE CATALOGS

HELLIGE
INCORPORATED
3718 NORTHERN BLVD. LONG ISLAND CITY 1, N.Y.
HEADQUARTERS FOR COLORIMETRIC APPARATUS

GENERAL ZOOLOGY LABORATORY GUIDE

by JAMES T. TANNER,
University of Tennessee

This new manual differs from others in the same field by combining the following features: Numerous figures and diagrams which aid the student in learning the anatomy of the specimens; specific questions for the student which can be answered by examination of the specimens; a series of general questions for discussion and review; suggestions for advanced or optional laboratory work for the faster students.

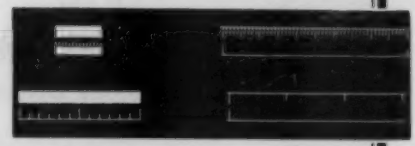
PRICE $2.25

Send for an On-Approval Copy

BURGESS PUBLISHING COMPANY
426 SOUTH SIXTH STREET · MINNEAPOLIS 15, MINNESOTA

Obtain instrument-like scales on YOUR Kymograph charts

Trace an improved time scale on your kymograph charts with the



FRANZ KYMO TIMER

Mount it on any laboratory stand—plug into any A.C. 110 volt 60 cycle circuit

Operate your kymograph at ANY speed. You will always mark a time scale of instrument quality and of the finest readable divisions with your FRANZ KYMO TIMER. Two scales are traced simultaneously, the upper recording in 1/5 second and one-second intervals, the lower recording in 10 second and one minute intervals. It automatically expands or contracts its scale to match the kymograph speed. No adjustments required over the entire range.

Price, complete in carrying case—Soot-writing type $24.00
Ink-writing type $30.00

■ *Order now, or write for further details to*

F. FRANZ CO. • NEW HAVEN 11, CONN.

Pressing Saps, Juices, Extracts
Press out Spent Extractions
Pressing Mother Liquors from Crystals
Pressing out Vaccines and Viruses
Pressing Bacteria
Pressing Fluids from Animal Tissue
Pressing Concentrated Extracts
Plastic Molding, Forming, Blocking
Flow Tests
Extrusion and Extrusion Tests
Metallographic Mounting
Briquetting, Cake Forming
Compression Tests
Laminating and Vulcanizing

THE CARVER LABORATORY PRESS

the Standard Press of Many Uses...
...complete with Accessories for General Research
Some of the Many General Applications...
...for Quick—Accurate—Small Scale Tests
Send for Complete New Catalog

Send for your copy of this new handy-size manual containing up-to-date information on the Carver Laboratory Press and its many uses.

FRED S. CARVER INC.
HYDRAULIC EQUIPMENT
101 HUDSON ST., NEW YORK 14, N. Y.

Send catalog, describing Carver Laboratory Press and Standard Accessories.

NAME .....
FIRM .....
ADDRESS 130

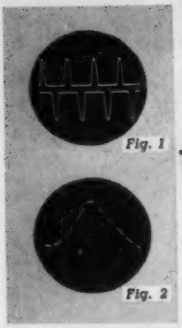


Fig. 1

Fig. 2

Add TIME MARKS to your C.R. 'SCOPE TRACE

THE BERKSHIRE LABMARKER

- Gives positive or negative pulses, or both at once
- Gives blanking pulses
- Times at 25 cycles to 1 mc.
- Changes sinusoidal waves, up to 30 volts RMS, to pulses $\frac{1}{3}$ cycle wide with peak value $\frac{1}{2}$ RMS input voltage
- Connects between oscillator and CR 'scope
- Is wholly self-contained
- Costs only $18.50 (Del'd in U. S. A.)

Fig. 1 Connected to "Y" input

Fig. 2 Connected to "Z" input

SEND US YOUR ORDER TODAY

BERKSHIRE LABORATORIES
610 Lexington Road, Concord, Mass.

PHOTOVOLT
Line-Operated Electronic MULTIPLIER-PHOTOMETER
Mod. 520-M

For the exact measurement of extremely low light values down to 1/10,000 microlumen.

Write for Bulletin #360 to

PHOTOVOLT CORP.
95 Madison Ave. New York 16, N. Y.

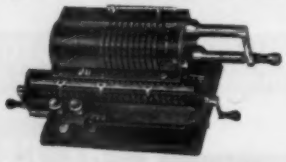
SERVALL

ANGLE CENTRIFUGES
Ask for Bulletin EO-101 with complete data on all models

Type SS-1 (Superspeed)

With safety design self-centering device and dynamical balance. 13,000 r.p.m. 20,000 × G. Cap. 8 × 50cc or 15cc tubes.

New Type SS-2 Vacuum Centrifuge
19,000 r.p.m. 60,000 × G.
Capacity 16 × 50cc or 15cc tubes



ORIGINAL—ODHNER
Portable Calculator for the Scientist
With exclusive back transfer device
Efficient ● Sturdy ● Low Priced
Ask for Bulletin EO-103

SERVALL
Magnetic Stirrer
Ask for Bulletin EO-104

Stirs
- in open vessels
- in closed systems
- under pressure
- under sterile conditions

NEW Thermostatically Controlled Swingable Heating Plate

Novel, Shock Resistant, Glass-encased Stirring Elements **NEW**

Manufacturers and Distributors
IVAN SORVALL, Inc.
210 Fifth Ave., New York 10, N. Y.

Annual Review of **Physical Chemistry** VOLUME 2

"... the editors and publishers are to be congratulated on an excellent service to physical chemists and chemistry.... If teachers of physical chemistry will use this text annually their later instruction will reflect the effort. Graduate students can use it as a mine of suggestions for research topics. Especially should it be useful to those Ph.D.'s who, having left academic halls, tend to overlook the broad pathways of scientific advance in their attention to a more specialized or industrial objective." (*Chemical and Engineering News*, February 12, 1951.)

EDITOR: G. K. Rollefson; ASSOCIATE EDITOR: R. E. Powell
EDITORIAL COMMITTEE: H. Eyring, G. Glockler, W. F. Libby, J. W. Williams, and E. B. Wilson, Jr.

CONTENTS: Thermodynamics and Thermodynamic Properties of Substances, J. G. Aston, J. J. Fritz, and E. J. Rock; Heterogeneous Equilibria and Phase Diagrams, W. N. Lacey and B. H. Sage; Solutions of Electrolytes, H. S. Harned; Solutions of Nonelectrolytes, F. P. Buff and J. G. Kirkwood; Isotopes, D. W. Stewart; Radioactivity and Nuclear Theory, G. T. Seaborg and D. H. Templeton; Radiation Chemistry, F. S. Dainton and E. Collinson; Spectroscopy, L. G. S. Brooker and W. T. Simpson; Microwave Spectroscopy of Gases, E. B. Wilson, Jr.; Quantum Theory, G. E. Kimball; Band Theory and Crystal Structure, R. Smoluchowski and J. S. Koehler; Experimental Molecular Structure, W. L. Roth; Experimental Crystallography, R. E. Rundle; Homogeneous Chemical Kinetics, M. Kilpatrick; Contact Catalysis and Surface Chemistry, P. H. Emmett; Ion Exchange, G. E. Boyd; Photochemistry, F. E. Blacet and J. G. Calvert; Photosynthesis, E. Rabinowitch; Thermodynamics of High Polymer Solutions, P. J. Flory and W. R. Krigbaum; Colloid Chemistry (Exclusive of High Polymers), J. W. Williams.

Approximately 450 pages • Cloth bound • Subject and author indexes

OFF THE PRESS: September 15, approximately

PUBLISHED BY: Annual Reviews, Inc., Stanford, California, U.S.A.

PRICE: $6.00 plus shipping (U.S.A. and Pan America, 15 cents) Elsewhere, 35 cents)

ON SALE BY: **ANNUAL REVIEWS, INC.,** STANFORD, CALIFORNIA, U.S.A.

FOR ROUTINE HIGH-CENTRIFUGAL FORCE

An ultracentrifuge to concentrate, purify, and classify macromolecules and colloidal materials—proteins, viruses, enzymes, chemical precipitates, etc.

Interchangeable angle-type rotors run in vacuum chamber equipped with refrigeration for controlled rotor temperatures.

Automatic electronic controls govern the entire fast cycle of operation, monitor the self-balancing quiet 40,000-rpm electric drive. Double armor-steel guard and interlocks combine safety with dependability.

Send for complete information on Model L Preparative Ultracentrifuge

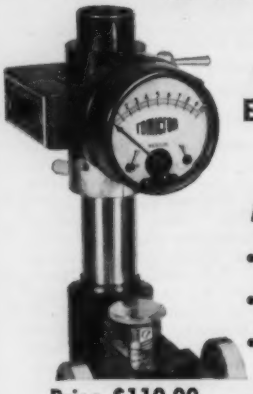
spinco **SPECIALIZED INSTRUMENTS CORPORATION**
605 O'NEILL AVE., BELMONT, CALIF.

romicron

C. G. Grand

MICROPHOTOMETER

Patent Pending



FOR DETERMINING EXPOSURE TIME IN PHOTO-MICROGRAPHY

- removal from microscope unnecessary
- adaptable to any standard microscope
- readings are conveniently taken by moving a lever

Price $110.00

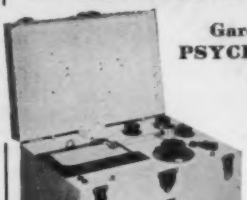
Write for pamphlet S-4

PAUL ROSENTHAL

505 Fifth Avenue New York 17, N. Y.

MICROSCOPES & SCIENTIFIC APPARATUS

For MEASUREMENT of SKIN RESISTANCE



Garceau RECORDING PSYCHOGALVANOMETER

For the study of the psychogalvanic reflex and skin resistance. The instrument is direct-reading and gives a written record of the reaction of the patient.

Price $775.00

Garceau CLINICAL DERMOHMETER

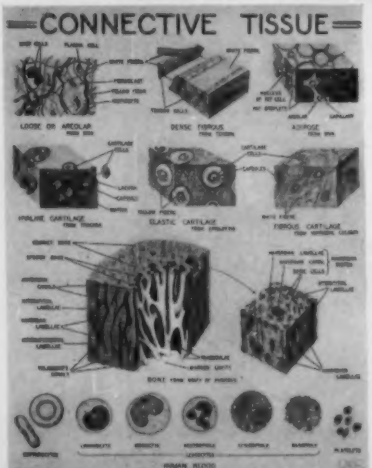
For clinical and experimental investigation of disorders involving sympathetic reaction, such as pain reflexes. In the psychological laboratory, the instrument has a well-known application as a so-called "lie detector". Resistance is read directly from a calibrated dial. Small variations, greatly magnified, are shown on the meter. Battery operated. Price $115.00

ELECTRO-MEDICAL LABORATORY, INC.

New Address–SOUTH WOODSTOCK 2, VERMONT, U.S.A.

Pioneer manufacturers of the electroencephalograph

HISTOLOGY CHARTS AND TEST SHEETS



A new series of four "NYSSCO" Charts, (offered both colored and uncolored), and accompanying series of nine unlabelled Laboratory Note-Book and Test Sheets. Figures on the latter are uncolored reductions of those on the four charts.

These charts meet a long-felt need of biology courses, on both secondary and college levels, in medical and nurses' training schools, etc. They are well-planned, with the figures beautifully executed and scientifically accurate.

The charts are cloth-backed, 36" × 50". With wood rollers, in plain black and white—$5.25, in color—$7.25. The Test Sheets (8½" × 11")—$2.75 per C, $.50 per dozen, of a kind.

Chart No.*	Titles	Test Sheet No.
1000	Epithelial Tissue	BT 1000A,B
1005	Connective Tissue	BT 1005A,B
1010	Muscular Tissue	BT 1010A,B
1015	Nervous Tissue	BT 1015A,B,C

* When ordering, indicate "plain" or "colored".

EST. NYSSCO 1919

Ask for Cat. No. 7J-"NYSSCO Biology Models and Charts."

NEW YORK SCIENTIFIC SUPPLY CO.

28 West 30th St. New York 1, N. Y.

Scientists agree: there is no better microscope lamp....

LINDLY ALL-PURPOSE Brilliant, adjustable, variable intensity illumination for exacting microscopy. $32.75

LINDLY BRIGHT-BEAM Variable Intensity Illumination designed for Stereoscopic Opaque, Dissecting microscopy, great adjustability. $27.50

Universal Clamp with ext. rod. $4.80

LINDLY VBM Extra brilliant, Variable Intensity for Binocular and Monocular microscopes. ... $8.95

LINDLY BM All the features of VBM except Intensity change. Sturdy, attractive, switch-on cord. $5.75

See your dealer or write for folders.
LINDLY & CO.
80 Herricks Rd.
Mineola, N. Y.

'LINDLY'
FOREMOST IN MICROSCOPE LAMPS

Paper Partition CHROMATOGRAPHY Equipment

Cabinets
Cylinders & Racks
Miscellaneous
Accessory Equipment
Specially
Designed for
Paper Partition
Chromatographic
Analysis

CHROMATOCAB
Model B300—Insulated

Write for Descriptive Brochure

BERKELEY CHROMATOGRAPHY DIV.
University Apparatus Company
Dept. H • 2229 McGee Avenue • Berkeley 3, Calif.

NEW 1952 ALLIED CATALOG

Send for it

FREE
THE COMPLETE 212-PAGE BUYING GUIDE

world's largest stocks of ELECTRONIC SUPPLIES for laboratory, classroom and industrial application

Save time, effort and money—send your consolidated orders to ALLIED—the single, complete source for *all* Electronic Supplies. Depend on ALLIED for quick shipment from the world's largest stocks of special tubes, test instruments, parts components, audio equipment, accessories—complete quality lines of electronic apparatus. We specialize in the expert supply of Electronic Equipment for research and development work, for classroom instruction, and for maintenance and production operations in industry. Send today for your FREE copy of the 1952 ALLIED Catalog—the only *complete, up-to-date* guide to Electronic Supplies for laboratory, classroom and industrial use.

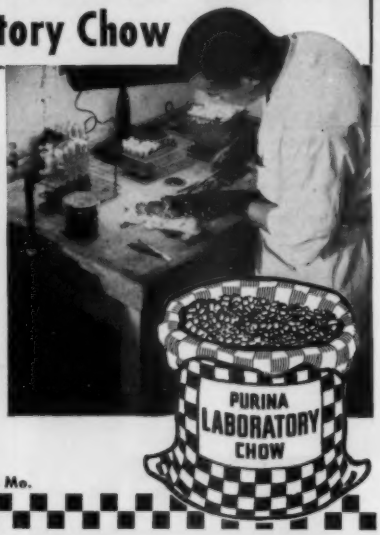
One Complete, Dependable Source for Everything in Electronics

We are specialists in the supply of High-Fidelity custom audio components. Look to us for Hi-Fi amplifiers, tuners, speakers, record changers and accessory equipment.

SEND FOR FREE 1952 CATALOG

ALLIED RADIO
833 W. JACKSON BLVD., Dept. 53-K-1, CHICAGO 7, ILL.

When Uniformity Counts So Much . . . Feed Purina Laboratory Chow



Purina Laboratory Chow is important to scientists using experimental animals over long periods of time. Here the main problem is a uniform diet.

Purina Laboratory Chow is made from a formula that never changes. Purina Research Scientists constantly test its chemical, mineral and vitamin content. Only select ingredients of good nutritional quality are used in its manufacture.

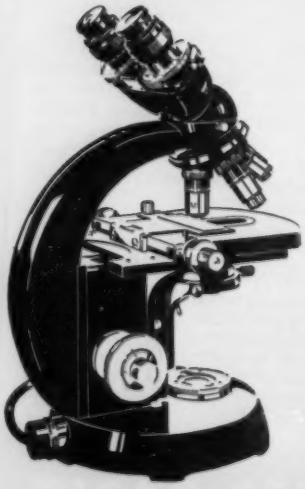
In its complete Checker form, your animal care is simplified. Call on your local Purina Dealer or write to our Laboratory Chow Department for information.

RALSTON PURINA COMPANY • St. Louis 2, Mo.

NEW—MICROSCOPES—REBUILT

ZEISS

ALL MAKES



GRAF APSCO

ZEISS-GF325 oculars. Paired 8×, 12.5× Objectives in quadruple nosepiece. Achromatic 2.5× 16mm. 10× 4mm. 40× 100× oil im. Built-in graduated mechanical stage, in case $516.00 with mirror. Illuminator as illustrated $76.39 extra.

Bausch & Lomb Spencer or Leitz now available at same price Model CS2 (B & L illustrated) Equipped with: 10× ocular 2 objectives (16mm & 4mm) iris diaphragm double mirror plano/concave) $85.00 each Guaranteed mechanically optically. Write for catalogue

Write for complete list of rebuilt RESEARCH MICROSCOPES.

THE GRAF-APSCO COMPANY

5868 Broadway

Chicago 40, ILL.

For MAXIMUM OPERATING CONVENIENCE

AMINCO LARDY

Rotary Warburg Apparatus

This greatly improved design represents the most modern developments in manometric apparatus. In addition to temperature controls of proven dependability and sensitivity (plus-minus 0.02°C.), the apparatus offers the outstanding performance and convenience features given below, several of which are exclusive with Aminco. Heated models (room to 50°C.) and refrigerated models (10° to 50° C.) are available as standard.

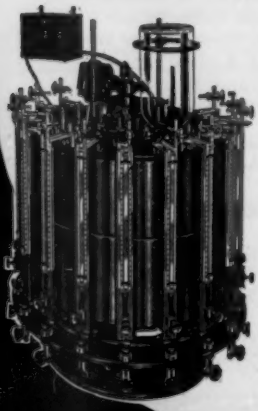
●

Manometers stopped individually by mere twist of convenient knob.

Rotatable—operator can bring any manometer before him without changing his position.

Manometers read easily while in motion . . . Manometers will not wobble.

Manometer holders easily removed by exclusive release mechanism.



Numbers on manometer stations easily identify manometers.

Water lost by evaporation automatically replaced . . . no plumbing connections necessary.

Rotatable gassing manifold available.

Flask oscillation adjustable as to speed and amplitude.

Quiet in operation.

Accommodates various types of manometers.

●

Illustrated: Heated Model Rotary Apparatus; conventional rectangular type also available.

Write for Bulletin 2168-K

AMINCO — Since 1919 — AMERICAN INSTRUMENT CO., Inc. — Scientific Instruments — SILVER SPRING, MARYLAND

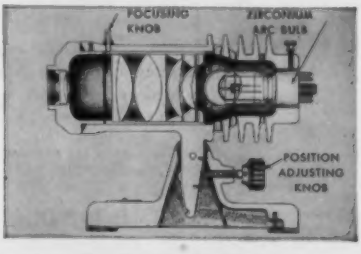
NUCLEOPROTEINS and DERIVATIVES

Adenosine Triphosphate
Adenine
Adenine Sulfate
Adenylic Acid
Adenosine
Cozymase
Cytidine
Cytidine Sulfate
Cytidylic Acid
Cytosine
Desoxyribonucleic Acid
Fructose-6-Phosphate (Barium)
Glucose-1-Phosphate (Potassium)
Glutathione
Guanine
Guanine Hydrochloride
Guanosine
Guanylic Acid
Hexose Diphosphate
Hypoxanthine
Inosine
Iron Nucleate
Manganese Nucleate
6 Methyl Uracil
Nucleic Acid (Ribose Nucleic Acid)
Protamine Nucleate
Phosphoglyceric Acid
d Ribose
Sodium Nucleate
Sodium Desoxyribonucleate
Ammonium Uridylate
Thymine (5 Methyl Uracil)
Uracil
Uridine
Uridylic Acid
Uramil
Xanthine
Xanthosine

Write for Revised Catalogue S#901 Listing a Complete Selection of Nearly 500 Important Biochemicals

NUTRITIONAL BIOCHEMICALS CORP.
21010 Miles Avenue • Cleveland 28, Ohio

New
Radically different!



"ZIRCONARC" PHOTOMICROGRAPHIC LAMP

For better black-and-white and color photomicrographs

Combines the concentrated light of the Western Union arc light bulb (about 1 mm dia.) with our fluorite-coated, 7-element aplanatic optical system of highest correction, free from chromatic aberration. . . . Practically harmless to living cultures. . . . Built with the same precision as the microscope itself. Over-all length of lamp, 10". Height, 6½". Base, 4½" × 6¼". Price, complete with power unit and 40-watt bulb, $325. Order direct or from leading supply dealers.

Write for Bulletin ZL-321S

FISH-SCHURMAN CORPORATION
74 Portman Road, New Rochelle, N. Y.

Fish-Schurman

REGISTER NOW

for the Philadelphia Meeting of the AAAS

AVOID CONGESTION AND DELAY
GET YOUR GENERAL PROGRAM –
BY FIRST CLASS MAIL – EARLY IN DECEMBER

Registration in *advance* of arrival at the 118th Annual Meeting of the AAAS in Philadelphia, December 26–31, 1951, has several striking advantages:

1. You avoid congestion and delay at Registration Desks at time of arrival. All indications point to a large attendance since all of the Association's eighteen sections and subsections, and more than forty societies, have excellent programs, and, in addition to paper-reading sessions, there will be the important symposia, conferences, and addresses for which an AAAS Meeting is noted.
2. You receive the General Program early in December in ample time, unhurriedly, to decide among the events and the sessions that you particularly wish to attend.
3. Your name will be in the Visible Directory the first hour of the first day of the meetings, since it will be posted in Washington as soon as received. (Hotel address can be added later, if necessary.)
4. Advance Registrants have the same privileges of receiving a map and directory of points of interest in Philadelphia, literature, radio broadcast tickets, etc. At the convenience of Advance Registrants, these will be distributed from the Main Registration in the Municipal Auditorium—the location of the full-scale Annual Exposition of Science and Industry, the Visible Directory, the AAAS Science Theatre, and the Biologists' Smoker.

To insure its prompt receipt, the General Program will be sent *by first class mail* December 1–6, 1951—which last is also the closing date for Advance Registration.

---------- **THIS IS YOUR ADVANCE REGISTRATION COUPON** ----------

1. Advance Registration Fee (the extra quarter covers part of the first class postage) enclosed:
   ☐ **$2.25 AAAS Member** (check one) ☐ **$2.25 College Student**
   ☐ **$2.25 Wife (or Husband) of Registrant** ☐ **$3.25 Nonmember of AAAS**
2. FULL NAME (Dr., Miss, etc.) .....
   (Please print or typewrite) (Last) (First) (Initial)
3. ACADEMIC, PROFESSIONAL, OR BUSINESS CONNECTION .....
4. OFFICE OR HOME ADDRESS .....
   (For receipt of Program and Badge)
5. YOUR FIELD OF INTEREST .....
6. CONVENTION ADDRESS .....
   (If not known now may be added later)
7. DATE OF ARRIVAL ..... DATE OF DEPARTURE .....

Please mail this Coupon and your check or money order for the fee, $2.25 or $3.25, to
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
1515 Massachusetts Avenue, N.W., Washington 5, D. C.

HOTEL RESERVATIONS

118th AAAS MEETING

Philadelphia, December 26-31, 1951

The list of hotels and the reservation coupon below are for your convenience in making your hotel room reservation in Philadelphia. Please send your application, *not* to any hotel directly, but to the AAAS Housing Bureau in Philadelphia and thereby avoid delay and confusion. The experienced Housing Bureau will make assignments promptly; a confirmation will be sent you in two weeks or less. **Share a room with a colleague if you wish to keep down expenses.** Mail your application *now* to secure your first choice of desired accommodations.

HOTELS AND RATES PER DAY

Hotel★	Single	Double	Twin-Bedded	Suites
ADELPHIA★	$5.00–$6.00	$7.50–$10.50	$10.00–$12.50	$25.00–$35.00
BARCLAY			$ 8.00–$12.00	$14.00–$25.00
BELLEVUE–STRATFORD★	$4.50–$6.00	$8.00–$10.00	$ 9.00–$12.00	$20.00–$30.00
BENJAMIN FRANKLIN★	$5.00–$7.50	$8.00–$10.50	$11.00–$13.00	$18.00
DRAKE	$6.00	$ 7.00	$ 9.00	$15.00
ESSEX	$4.75–$5.00	$6.00–$ 8.50	$ 9.00–$10.00	
JOHN BARTRAM★	$3.25–$4.50	$5.00–$ 8.00	$ 7.00–$ 9.00	
PENN SHERATON	$5.00–$7.50	$7.50–$10.00	$ 8.00–$10.50	$12.00–$15.00
RITZ–CARLTON★	$7.00–$7.50		$11.00–$12.00	
ROBERT MORRIS	$4.50–$5.00	$7.00–$ 8.00	$ 8.00	
ST. JAMES	$4.00–$5.50	$6.00–$ 8.00	$ 6.50–$ 9.00	
SYLVANIA★			$ 9.00–$11.00	$18.00
WARWICK			$ 9.00–$12.00	$22.00–$24.00

Cots added to a room are $2.50 each; dormitory style rooms (for 5 or more) are $3.50 per person.

★ **Hotels starred have sessions in their public rooms.** For a list of the headquarters of each participating society and section, please see **Association Affairs,** *Science*, August 24, or *The Scientific Monthly*, September.

THIS IS YOUR HOTEL RESERVATION COUPON

AAAS Housing Bureau
Architects Building (1st Floor)
Philadelphia 3, Pa.

Date of Application .....

Please reserve the following accommodations for the 118th Meeting of the AAAS:

TYPE OF ACCOMMODATION DESIRED

...Single Room(s) Desired Rate ..... Maximum Rate .....

...Double Room(s) Desired Rate ..... Maximum Rate ..... Number in Party .....

...Twin-Bedded Room(s) Desired Rate ..... Maximum Rate .....

...Suite(s) Desired Rate ..... Maximum Rate ..... Sharing this room will be:

.....(*Enumerate persons here and attach list giving name and address of each person, including yourself*)

CHOICE OF HOTEL

First Choice ..... Second Choice ..... Third Choice .....

DATE OF ARRIVAL ..... DEPARTURE DATE .....
(These *must* be indicated)

NAME .....
(Please print or type)

ADDRESS .....
(Street) (City and Zone) (State)

Mail this now to the Housing Bureau. **Rooms will be assigned and confirmed in order of receipt of reservation.**

New! Simplified!

PIPETTE WASHER

Inexpensively Priced!

Converts any container, of suitable depth, into a pipette washer. Works automatically and rapidly. Can be used with standard rubber or plastic tubing, of proper length, in any container. This device will wash a 1,000 cc graduate at a rate of 60 changes per hour. Made of "Pyrex" glass.

$7.50 each

F.O.B. BALTO., MD.
Net 30 days.
10% discount given on orders of 12 or more.

Territories Available For Hospital and Laboratory Supply Houses

BALTO. SYPHON SUPPLY CO.
2220 E. FAIRMOUNT AVE.
Baltimore 31 Md. PEabody 7100

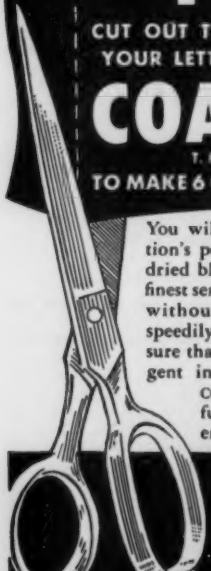
FREE!

CUT OUT THIS AD AND PIN IT TO YOUR LETTERHEAD FOR ENOUGH

COAGUSOL

T. M. REG. U. S. PAT. OFF.

TO MAKE 6 GALLONS OF SOLUTION!



You will find that a COAGUSOL solution's penetrating action strips stains, dried blood and tissue from even the finest serration of surgical instruments, without soap, without scrubbing—speedily, economically. Because we are sure that you will find this new detergent invaluable—we ask you to try COAGUSOL at our expense. For full information and your generous sample, write right now to

HOSPITAL LIQUIDS Incorporated
2900 S. Michigan Avenue
Chicago 16, Ill.
Laboratories at Chicago, U. S. A.

. . . A NEW BOOK
and a popular favorite

Stages in the Evolution of Plant Species

By *JENS CLAUSEN*, *Department of Plant Biology, Carnegie Institution of Washington, Stanford, California*

• A lucid account of the dynamics of evolution in higher plants—from the small differences between individuals within a single local wild population to the large differences that distinguish genera.

The book is based upon intensive co-ordinated experimental work on genetic, cytologic, and transplanting experiments on various plant groups. The data are integrated into a broad picture of relationships that are of general biological interest—not only for the interpretation of the structure of present-day species, but also with regard to the possible course of past and future evolution.

76 ILLUSTRATIONS, $3.75

BEES: Their Vision, Chemical Senses, and Language

By *KARL VON FRISCH*, *Professor of Zoology, The University of Munich*

"This little book, based on Dr. von Frisch's startling lectures at Cornell University in 1949, opens new horizons in insect 'intelligence'. There is no Maeterlinckian mysticism in this scientist's report; he merely tells what he trained bees to do . . . other scientists have confirmed his amazing results."—*N. Y. Herald Tribune*

61 ILLUSTRATIONS, $3.00

CORNELL UNIVERSITY PRESS
124 Roberts Place Ithaca, N. Y.

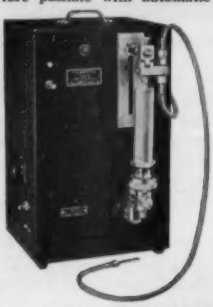
10 TIMES GREATER ACCURACY!

Pipette automatically to .001 c.c. precision

FILAMATIC

Electronically Regulated Automatic Pipette

In tests at leading research center in Baltimore,* the Filamatic dispensed volumes from 0.5 c.c. to 1.0 c.c. with an average variation of .001 c.c. This accuracy was reproducible on re-runs without trial and error manipulation. Amazing results prove Filamatic 10 times more accurate than heretofore possible with automatic pipetting machines!



- **Electronic control—Maintains constant motor torque at all speeds.**
- **Wide filling range—.025 c.c. to 50 c.c. without costly attachments.**
- **Adjustable speed—10 to 90 deliveries per minute.**
- **Heavy duty, 1/30 HP Gearmotor.**
- **Micrometer type adjustment of delivery volume.**
- **Aseptic filling unit—Instantly removable for cleaning or sterilizing.**

Ask your dealer for demonstration or write for bulletin S-10

NATIONAL INSTRUMENT COMPANY

5005 Queensbury Ave. • Baltimore 15, Md.

*** Name upon request.**

THE MICRO-FLOW REGULATOR

Here is a new clamp for regulation of flow through plastic or rubber tubing, 0"—⅜".

Adjusts by smooth-acting ratchet which permits minute changes of flow for infusions etc., with ready return to a former rate. One "click" equals .00078" movement of the pressure plate.

Constructed entirely of stainless steel, with the traditionally fine workmanship of the Harvard Apparatus Company, Inc. The cut shows actual size.

From stock, $5.00

Catalogue and price-list sent on request.

THE HARVARD APPARATUS COMPANY, INC.

Dover **Massachusetts**

KLETT ELECTROPHORESIS

CUSTOM MADE

TOOL FOR THE ANALYSIS OF COMPLEX COLLOID SYSTEMS, AND FOR THE CONTROL OF PRODUCTION OF PURIFIED PROTEINS, ENZYMES, HORMONES

KLETT MANUFACTURING CO.

179 EAST 87TH STREET

NEW YORK, N. Y.

Genetics and the Origin of Species

THIRD EDITION, REVISED

THEODOSIUS DOBZHANSKY

Completely rewritten to cover the many new developments in the field of evolutionary biology since the second edition. Of the previous edition, *Science* said: "It is the best book on genetics and evolution ever written." *November* $5.00

A Dictionary of Antibiosis

LEONARD KAREL and ELIZABETH SPENCER ROACH

A comprehensive and authoritative reference volume. Thousands of alphabetically arranged listings of plants, both lower and higher forms, from which antibiotic substances are derived; of microscopic forms used as test organisms; and of specific antibiotic substances. For each antibiotic substance is listed, when available, the source of the substance, how it is extracted, its chemical and physical properties, spectrum *in vitro* and *in vivo*, in some cases structural formulas, and toxological, pharmacological, and clinical results. $8.50

Eclipses of the Sun

FIFTH EDITION

S. A. MITCHELL

Both a history of eclipses from Biblical times to the present and a treatise on the structure of the atom and on the interpretation of eclipse observations. Includes information on the recent Einstein relativity shift and the recent spectroscopic successes attained in studies of temperatures and pressures, and the distribution and abundance of elements in the sun's atmosphere. *December* $6.50

COLUMBIA UNIVERSITY PRESS • NEW YORK 27

Publishers of the Columbia Encyclopedia

Meetings & Conferences

Oct. 10–13. Photographic Society of America. Detroit.

Oct. 13. Symposium on Molecular Spectroscopy, Purdue Section, American Chemical Society. Lafayette, Ind.

Oct. 14–15. Association Canadienne-Française pour l'Avancement des Sciences. Montreal, Canada.

Oct. 15–17. American Gas Association (Annual). Kiel Auditorium, St. Louis.

Oct. 15–18. American Dental Association (Annual). Washington.

Oct. 15–19. National Metal Congress and Exposition. Detroit, Mich.

Oct. 15–19. World Metallurgical Congress (Annual). Detroit, Mich.

Oct. 16–19. American Society of Clinical Pathologists (Annual). The Drake, Chicago.

Oct. 17–19. American Association of Textile Chemists and Colorists. Hotel Statler, New York.

Oct. 18–20. American Association of Petroleum Geologists (Regional). Commodore Perry Hotel, Austin, Tex.

Oct. 20–26. First Pan American Congress on Veterinary Medicine. Lima, Peru.

Oct. 21–24. American Mining Congress (National). Biltmore Hotel, Los Angeles.

Oct. 22–23. Independent Petroleum Association of America (Annual). The Shamrock, Houston, Tex.

Oct. 22–24. American Association of Blood Banks (Annual). Hotel Nicollet, Minneapolis.

Oct. 22–24. American Standards Association (Annual). Waldorf-Astoria, New York.

Oct. 22–24. National Electronics Conference and Exhibition. Edgewater Beach Hotel, Chicago.

Oct. 22–25. American Academy of Pediatrics (Annual). Royal York Hotel, Toronto.

Oct. 22–26. American Institute of Electrical Engineers (Fall). Hotel Cleveland, Cleveland.

Oct. 23. Association of Consulting Chemists and Chemical Engineers (Annual). New York.

Oct. 23–24. Optical Society of America (Annual). Hotel Sherman, Chicago.

Oct. 24–27. American Physical Society. Chicago.

Oct. 25. Society of Exploration Geophysicists (Eastern). Webster Hall Hotel, Pittsburgh.

Oct. 25–26. American Institute of Mining and Metallurgical Engineers (Annual fall, Petroleum Branch). Elks Club, Los Angeles.

Oct. 29–30. Society of Automotive Engineers (National Diesel Engine meeting), The Drake, Chicago; (National Transportation), Knickerbocker Hotel, Chicago, Oct. 29–31; (National Fuels and Lubricants), The Drake, Oct. 31–Nov. 1.

Oct. 29–31. Conference on Electrical Insulation (Annual). National Bureau of Standards, Washington.

Oct. 29–31. National Lubricating Grease Institute (Annual). Edgewater Beach Hotel, Chicago.

Oct. 29–Nov. 2. American Public Health Association. Civic Auditorium, San Francisco.

Oct. 29–Nov. 3. National Paint, Varnish, and Lacquer Association. Chalfonte-Haddon Hall, Atlantic City.

Oct. 29–Nov. 3. Primer Congreso Nacional de Ingenieria Civil. Ciudad de Monterrey, Mexico.

Oct. 29–Nov. 16. Inter-Agency Institute for Hospital Administrators. Federal Security Agency, Washington.

Nov. 1–3. American Physical Society, Division of Electron Physics. National Bureau of Standards, Washington.

3 NEW ORGANIC CHEMISTRY WORKS

Just Published

CHEMISTRY OF WOOD

By ERIK HÄGGLUND
Swedish Forest Products Research Laboratory, Stockholm

x, 631 pages, 1,959 references, illustrated, $13.50

Completely up-to-date, Dr. Hägglund's book is a most comprehensive one-volume treatise now available in English for the first time. An expert by training and experience the author presents in integrated form the vast amount of data on the properties and behavior of wood. The volume is likely to become the standard reference in the field and an almost indispensable companion to research workers and graduate students whose interests range over the many facets of wood chemistry.

CONTENTS

The Wood Tissue—The Physical Properties of Wood—The Wood Components and Their Chemical Properties—The Decomposition of Wood by Acids. Wood Saccharification—The Pulping of Wood with Solutions of Sulfurous Acid and Sulfites—The Pulping of Wood by Aqueous Alkalies—Other Methods of Pulping—Delignification with Bleaching Agents—The Chemical Process in the Carbonization of Wood—Utilization of Wood by Caustic Fusion, Pressure Heating with Alkali and Digestion with Tars or Phenols—The Behavior of Wood during Storage—The Natural Decomposition of Wood—Author Index—Subject Index

Ready November 1951

THE CHEMISTRY OF LIGNIN

By F. E. BRAUNS
The Institute of Paper Chemistry, Appleton, Wisconsin

xvi, 808 pages, illustrated, $14.50

The Chemistry of Lignin is the first book to include the work of the past twenty-five years on this most important raw material, and the first to be published in English.

CONTENTS

Introduction—The Evolution of Lignin Chemistry—The Definition and Distribution of Lignin—Color Reactions of Lignified Materials—The Isolation of Lignin—The Determination of Lignin—The Physical Properties of Lignin—The Elementary Composition and Constituent Groups of Lignin—The Acylation and Acylysis of Lignin—The Alkylation of Lignin—The Halogenation of Lignin—The Nitration of Lignin—The Sulfonation of Lignin—The Hydrolysis of Lignin—The Alcoholysis of Lignin—The Mercaptolysis of Lignin—The Phenolysis of Lignin—Reduction, Hydrogenation, and Hydrogenolysis of Lignin—The Oxidation of Lignin—The Alkali Fusion of Lignin—Special Reactions with Lignin—The Thermal Decomposition of Lignin—The Biological Decomposition of Lignin—Theories on the Structure of Lignin—The Linkage of Lignin in the Plant—Theories on the Formation of Lignin—Synthetic Lignins—Appendix—Author Index—Subject Index

Volume I—Ready October 1951

THE CHEMISTRY OF SYNTHETIC DYES

(Complete in 2 volumes)

By K. VENKATARAMAN
Director, Department of Chemical Technology, University of Bombay, India

Professor Venkataraman discusses the structure and synthesis of dyes against the general background of developments in the theory and practice of organic chemistry. For this comprehensive modern monograph all the available sources of information have been used, especially the reports, documents and microfilms covering the German dyestuff industry.

Volume I, xii, 704 pages, illustrated, $14.50

CONTENTS

Introduction—Raw Materials—Intermediates—Diazotization and Diazonium Salts—Classification of Dyes—Application of Dyes—Color and its Measurement—Color and Chemical Constitution—Nitroso Dyes—Nitro Dyes—Azo Dyes-General—Monoazo and Disazo Dyes—Mordant Azo Dyes—Constitution of Metal-Dye Complexes—Trisazo and Polykisazo Dyes—Urea and Cyanuric Acid Derivatives—Direct Cotton Dyes Aftertreated on the Fiber—Pyrazolones—Thiazoles—Stilbene Dyes—Azo Dyes for Cellulose Acetate—Azoid Dyes

Volume II, Spring 1952, will cover the remaining dyes and include Indexes.

ACADEMIC PRESS Inc., Publishers, New York 10, New York

PERSONNEL PLACEMENT

YOUR ad here reaches over 32,000 foremost scientists in the leading educational institutions, industrial laboratories, and research foundations in the U. S. and 76 foreign countries—at a very low cost

CLASSIFIED: 15¢ per word, minimum charge $3.00 Use of Box Number counts as 10 additional words.

DISPLAY: $17.50 per inch, no charge for Box Number.

Correct payment to SCIENCE must accompany all ads. Insertion usually made 2 or 3 weeks after receipt of ad.

SCIENCE • 1515 Mass. Ave., N.W., Wash. 5, D. C.

POSITIONS WANTED

Bacteriologist: Experienced in production, control and Assay; Antibiotics, Feed Supplements. Desires Production Development work. Prefer East. Box 17, SCIENCE. X

Position Wanted:
Bacteriologist; Ph.D.; eight years' teaching experience (Bacteriology); four years, research bacteriologist and three years, director, development bacteriology, pharmaceutical industry; for further information, please write Science Division, Medical Bureau (Burneice Larson, Director), Palmolive Building, Chicago. X

Biologist: M.A. plus Ph.D. residence, college teacher of biology-geology wishes teaching or other work. Agricultural and varied lab. and field experiences. Botany, exology, vertebrates. Box 18, SCIENCE. X

Medical Parasitologist, Tropical Medicine: M.D., Ph.D., age 29, desires tenure position teaching or research in Medical College; industrial position considered. Teaching, research experience, broad training in U. S. and Tropics. Fluent Spanish, Portugese, French and Italian. Box 15, SCIENCE. X

POSITIONS OPEN

Analytical Chemist with at least 5 years experience. M.S. degree preferred; inorganic and organic analysis. Familiarity with modern techniques is essential such as infra-red analyses, photometry, etc. Work will be largely concerned with organic and inorganic fluorides. This is not routine work. Reply, giving resume of experience, education, usual personal information and salary requirements. Write Box S 1453, 221 W. 41 St., N. Y. 18, N. Y. 10/5

Biochemists: Research Institute, East, has opportunities for young Ph.D.'s in projects involving (1) protein fractionation, electrophoresis, ultracentrifugation, (2) characterization and isolation of microbiological growth factors. Experience in respective fields desired. Please give brief history. Box 558, SCIENCE. 10/12

SCIENTISTS—salaried positions, $3,600 to $25,000. This confidential service for outstanding men who desire a change of connection, will develop and conduct preliminary negotiations without risk to present position. Send name and address for details. **TOMSETT ASSOCIATES** • 335 Frick Bldg., Pittsburgh 19, Pa.

Positions Open:
(a) **Research Physiologist** or Pharmacologist; Ph.D., university medical school appointment; two-year grant; opportunity, original research; $5000–$8000. (b) **Two chemists;** advantageous if qualified in organic, physical or colloid chemistry with interest in development of products in medical and surgical fields; pharmaceutical company; East. (c) **Medical Writer;** should have medical science background with medical editorial experience and qualified for ethical copy writing; knowledge of French or German desirable. (d) **Ph.D. in Pharmaceutical Chemistry** or Biological Chemistry, to direct product development, well established company; university city; unusual. (e) **Biochemist;** M.A. degree; take charge of biological division, 300-bed general hospital; staff of 18; university center, Midwest. (f) **Chief Psychologist,** Ph.D.; $4800–$6000; state department of mental health. (g) **Pharmaceutical Chemist** or Biochemist; new product department; laboratories specializing in allergy products; West. S10-1 Science Division, Medical Bureau (Burneice Larson, Director) Palmolive Building, Chicago. X

Virologist, M.D. or Ph.D. Research, no routine diagnostic work; teaching optional. Experience in neurotropic viruses, poliomyelitis, tissue culture and animal work. Senior permanent position in medical school. Box 14, SCIENCE. 10/19

The MARKET PLACE

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

YOUR ad here reaches over 32,000 foremost scientists in the leading educational institutions, industrial laboratories, and research foundations in the U. S. and 76 foreign countries—at a very low cost

CLASSIFIED: 20¢ per word, minimum charge $5.00. Use of Box Number counts as 10 additional words. Correct payment to SCIENCE must accompany ad.

DISPLAY: Rates listed below—no charge for Box Number. Monthly invoices will be sent on a charge account basis —providing satisfactory credit is established.

Single insertion	**$17.50 per inch**
7 times in 1 year	**16.00 per inch**
13 times in 1 year	**14.00 per inch**
26 times in 1 year	**12.50 per inch**
52 times in 1 year	**11.00 per inch**

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

RESEARCH GRANTS

1952 ARCTIC RESEARCH GRANTS

The Arctic Institute of North America is offering a number of research grants in 1952 for scientific investigations dealing with arctic and subarctic regions. Research must include field investigations in North America or studies at one of the Institute offices. Completed applications must be received by 1st November 1951. Application forms may be obtained from: Research Committee, Arctic Institute of North America, Broadway at 156th Street, New York 32, N. Y., or 3485 University Street, Montreal, Canada.

BOOKS

BACK NUMBER PERIODICALS — Bought and Sold
• Tell us what you want!—What have you to offer?
Abrahams Magazine Service Established 1889 ▶ DEPT. P, 56 E. 13th ST. NEW YORK 3, N. Y.

Your sets and files of scientific journals are needed by our library and institutional customers. Please send us lists and description of periodical files you are willing to sell at high market prices. Write Dept. A3S, J. S. CANNER, INC. Boston 19, Massachusetts

SCIENTIFIC BOOKS and PERIODICALS WANTED
Complete libraries—Sets and runs—Single titles
Also, please send us your want lists.
STECHERT-HAFNER, INC.
31 East 10th St., New York 3

Entries in the **Fifth International Photography-in-Science Salon,** sponsored annually by THE SCIENTIFIC MONTHLY and the Smithsonian Institution, should be sent (prepaid) to the Editor, *The Scientific Monthly,* 1515 Massachusetts Ave., N.W., Washington 5, D. C., Nov. 1–Nov. 27. All accepted photographs will be shown at the AAAS meeting in Philadelphia Dec. 26–31, and later throughout the U. S. For entry blanks and full information write to the address given above.

The MARKET PLACE

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

YOUR ad here reaches over 32,000 foremost scientists in the leading educational institutions, industrial laboratories, and research foundations in the U. S. and 76 foreign countries—at a very low cost

CLASSIFIED: 20¢ per word, minimum charge $5.00. Use of Box Number counts as 10 additional words. Correct payment to SCIENCE must accompany ad.

DISPLAY: Rates listed below—no charge for Box Number. Monthly invoices will be sent on a charge account basis—providing satisfactory credit is established.

Single insertion	$17.50 per inch
7 times in 1 year	16.00 per inch
13 times in 1 year	14.00 per inch
26 times in 1 year	12.50 per inch
52 times in 1 year	11.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

BOOKS

WANTED TO PURCHASE . . .

SCIENTIFIC PERIODICALS and BOOKS

Sets and runs, foreign and domestic. Entire libraries and smaller collections wanted.

WALTER J. JOHNSON • 125 East 23rd St., New York 10, N. Y.

PROFESSIONAL SERVICES

SPECIAL GLASS APPARATUS

Our glass blowing department is available for special scientific and technical glass apparatus made to specifications and drawings. Inquiries invited. Estimates furnished.

E. MACHLETT & SON

218 East 23rd St. New York 10, N. Y.

SINCE 1870

New Food Ingredients • New Drugs

ANIMAL TESTS

Analyses • Consultation • Research

LaWall & Harrisson

Bacteriologists
Chemists • Pharmacologists

Div. S, 1921 Walnut St., Philadelphia 3, Pa.

SUPPLIES AND EQUIPMENT

—PLANT NUTRIENT TABLETS—

. . . for Plant Culture

Each tablet contains one gram of a nutrient. Saves the time of weighing out each ingredient for each experiment.

For experiment stations, hydroponics, high school and college classes in botany etc.

Write for leaflet PN-S

CARGILLE SCIENTIFIC INC., 118 Liberty St., New York, N. Y.

White SWISS Mice 20c and up

Rabbits, Cavies, White Rats, Ducks, Pigeons, Hamsters

Write • J. E. STOCKER • Ramsey, N. J.

PARASITOLOGICAL PREPARATIONS

• high quality — low priced. *Write for catalog*

TROPICAL BIOLOGICALS • P.O. Box 2227, San Juan, Puerto Rico.

SUPPLIES AND EQUIPMENT

STAINS

STARKMAN Biological Laboratory

• RARE
• COMMON
Price list on Request
• 461 Bloor St., W. Toronto, Canada

SODIUM IODIDE, THALLIUM-ACTIVATED CRYSTALS

Vacuum-sealed in quartz envelopes to insure permanency. Designed for scintillation work with standard photomultiplier tubes. Write for Bulletin SC-5. NUCLEAR RESEARCH CORP. 2707 Federal Street, Philadelphia 46, Pa. H

For CONSISTENT Rats . . .

• *BUDD MT. RODENT FARM*

• *CHESTER, N. J.*

Breeders of a recognized strain of Wistar.

L-PROLINE—Hydroxyproline, L-Methionine

• AMINO ACIDS • BIOCHEMICALS
• PRE-MIXED MICROBIOLOGICAL ASSAY MEDIA

H. M. CHEMICAL COMPANY, LTD.

144 North Hayworth Avenue Los Angeles 48, California

LABORATORY ANIMALS

• Clean healthy well-fed animals. Guaranteed suitable for your needs. Reasonably priced—Dependable service

DOGS RATS RABBITS
CATS PIGEONS HAMSTERS
MICE POULTRY GUINEA PIGS

JOHN C. LANDIS • Hagerstown, Md.

SPRAGUE-DAWLEY, INC.

Pioneers in development of the standard laboratory rat

Box 2071 • Madison 5, Wisconsin • Phone 36134

Simplified
ELECTROPHORETIC DETERMINATIONS
According to Durrum

Apparatus for Paper Method

Model A .... One Dimensional Method .... $19.25.
Jour. Am. Chem. Soc. 72; 2943, 1950.
Model B One or Two Dimensional Method . $37.50
Jour. Colloid Sci. 6; 274, 1951
Model C For Continuous Electrophoretic Separation and Recovery. Prices on Application.

DIOPTRIC ENGINEERING LABORATORIES
47 West 56th St., New York 19

Science writers are invited to write or wire to Westinghouse Awards, 1515 Massachusetts Ave., N.W., Washington 5, D. C., for details of the annual $1,000 AAAS-George Westinghouse Science Writing Awards for both newspaper and magazine writers. Nominations for the awards are also invited. Deadline for receipt of entries, which must be made in triplicate, is *Oct. 8.*

The MARKET PLACE

BOOKS • SERVICES • SUPPLIES • EQUIPMENT

YOUR ad here reaches over 32,000 foremost scientists in the leading educational institutions, industrial laboratories, and research foundations in the U. S. and 76 foreign countries—at a very low cost

CLASSIFIED: 20¢ per word, minimum charge $5.00. Use of Box Number counts as 10 additional words. Correct payment to SCIENCE must accompany ad.

DISPLAY: Rates listed below—no charge for Box Number. Monthly invoices will be sent on a charge account basis—providing satisfactory credit is established.

Single insertion	$17.50 per inch
7 times in 1 year	16.00 per inch
13 times in 1 year	14.00 per inch
26 times in 1 year	12.50 per inch
52 times in 1 year	11.00 per inch

For PROOFS on display ads, copy must reach SCIENCE 4 weeks before date of issue (Friday of every week).

SUPPLIES AND EQUIPMENT

FREE CATALOG No. 677..

Lists more than 300 items for Research—Biological, Microbiological, Bacteriological, Biochemical, Nutritional. Write

GBI 72 LABORATORY PARK CHAGRIN FALLS, OHIO

QUALITY WHITE RATS 39¢ AND UP

Start NOW to use rats selected from a vermin and disease free colony of homozygous and constant-reacting animals

Write: F. G. LURIE, 834 E. 90th ST. CHICAGO 19, ILL.

ANIMAL CAGES and ACCESSORY EQUIPMENT

BUY DIRECT FROM MANUFACTURER

HOELTGE BROS., Inc.

1919 Gest St. Cincinnati 4, Ohio

Write for Illustrated Catalog

LABORATORY ANIMALS

Mice, Rats, Hamsters, Guinea Pigs, Rabbits, Cats and Dogs

MANOR FARMS • STAATSBURG NEW YORK

Purity of Strain Guaranteed

All Amino Acids (natural, synthetic, unnatural), Rare Sugars, Biochemical Products, Reagents, New Pharmaceuticals in stock. Write or phone PLaza 7-8171 for complete price list.

BIOS LABORATORIES, INC. 17 West 60th Street, New York 23, N. Y.

SUPPLIES AND EQUIPMENT

RESEARCH ANIMAL FARMS

Albino Swiss Mice

Webster strain

66 Otsego St., Canajoharie, N.Y.

Phone 3-8212

Cannon AUTOMATIC DISPENSER-TITRATOR for microbiological assays and any routine dispensing and titrating — handles any series of volumes.

write to INTERNATIONAL INSTRUMENT CO., Los Angeles 15, Cal.

new HEINICKE micro illuminator

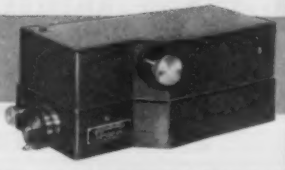
Designed by Dr. Kurt J. Heinicke, for the inclined binocular microscope—superb at all magnification levels. 3" clear, aspheric condensing system. Equal or bettter than $60.00 illuminators. **Price $9.50.** Please order directly or write for details.

HEINICKE Instrument Corporation

• P. O. BOX 2872 HOLLYWOOD, FLORIDA

ONE INSTRUMENT FOR THE

Ultraviolet Visible Infrared Range



FARRAND DOUBLE MONOCHROMATOR and SPECTROMETER

It is now possible to make spectral measurements in the ultraviolet, visible and infrared regions throughout the range of 0.2 to 35 microns—**WITH A SINGLE INSTRUMENT** by simply interchanging prisms.

The optical system comprises a double monochromator thereby reducing scattered radiations to a negligible magnitude. Highest spectral purity—Isolation of extremely narrow wave lengths and greatest resolution are obtained in any one chosen region by selection of prism material for optimum performance.

Bulletin No. 806 on request

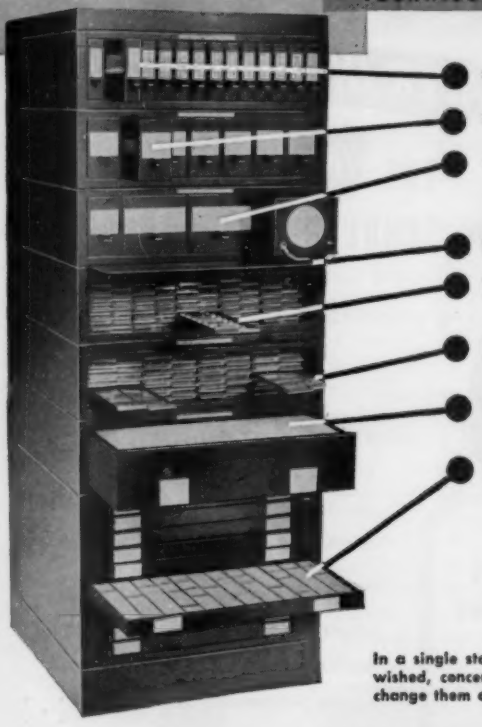
PRECISION OPTICS, ELECTRONIC AND SCIENTIFIC INSTRUMENTS

FARRAND OPTICAL CO., Inc.

BRONX BLVD. and EAST 238th STREET • NEW YORK 70, N. Y.

answer to every laboratory filing need

• TECHNICON *Lab • aid* FILE SYSTEM PAT. NO. 2,184,409 •



***1" MICROSLIDE DRAWERS**
(for spaced or storage filing)

***2" SLIDE OR TRANSPARENCY DRAWERS**
(for spaced or storage filing)

***4" DRAWERS**
(for 3¼" x 4¼" slides or index cards. Technilume drawer for built-in illumination optional)

SHELF
(for resting trays or drawers in use)

FLAT-FILING CABINET FOR MICROSLIDES
(slides lie flat in trays; dry quickly; are visible at a glance)

FLAT-FILING UNIT FOR TRANSPARENCIES
(2" x 2" or 3¼" x 4¼" for filing and instant viewing)

ILLUMINATION UNIT
(used in conjunction with Transparency Flat-Filing for viewing)

PARAFFIN BLOCK FILE
(shallow drawers, with vari-sized knock-down cardboard containers)

*Single cabinets can comprise variable assemblies of any of these drawers, thanks to the Technicon Lab-aid unit track design.

In a single stack of Technicon Lab-aid cabinets you could, if you wished, concentrate all these various facilities. Or add to them, change them about, even interchange the drawers in a single unit.

technicon *Lab-aid* filing system

engineered for efficiency . . . . . organized for economy

Every cubic inch of a Technicon Lab-aid filing unit is a live filing inch, without waste space for struts, dividers and the like. For instance, a single unit of 1" microslide drawers, used for close-packed storage filing, will accommodate approximately 6500 slides . . . a gain of up to 45% in capacity.

You can use a compact Lab-aid cabinet on your desk (it's only 19" square) or stack them to any height. Staunch welded-steel construction includes interlocking angles for stability and weight-supporting strength.

THE TECHNICON COMPANY — 215 EAST 149th ST., NEW YORK 51, N. Y.

Science Teachers Report

A GREAT TIME SAVER IN TEACHING

THE AO SPENCER SCHOLAR'S MICROSCOPE

HOW THE AO No. 78 SCHOLAR'S MICROSCOPE CUTS TEACHING TIME

1. Easy to learn to use.
2. Single focusing control—fast and precise.
3. Factory-focused built-in light source eliminates time consuming and frequently faulty substage adjustments.
4. Reversed arm position gives clearer view of specimen stage, objectives, and diaphragm openings.

Since we are currently supplying both military and civilian needs, instrument deliveries cannot always be immediate.

• The reports keep coming in—yes, the AO Scholar's Microscope *does* save time in teaching students microscopy.

This radically new idea in microscopes has proven a boon to science teachers. The built-in light source assures permanently aligned illumination and consequently better optical performance with much less adjustment. Low overall height increases comfort in operation. Locked-in parts reduce maintenance costs. 'Spring-loaded' focusing mechanism protects slides against damage. See your AO distributor or write Dept. X1.

American Optical

INSTRUMENT DIVISION • BUFFALO 15, NEW YORK